Market uptake of small modular renewable district heating and cooling grids for communities

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Guidelines on improved business models and financing schemes of small renewable heating and cooling grids

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CoolHeating website: www.coolheating.eu

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Abbreviations

BLT	Build Lease Transfer
BOO	Build Own Operate
BOOT	Build Own Operate Transfer
BOT	Build Operate Transfer
BRT	Build Rent Transfer
CHP	Combined heat and power
D&B	Design and Build
DBFO	Design Build Finance Operate
DH	District heating
DHC	District heating and cooling
EBRD	European Bank for Reconstruction and Development
EC	European Commission
EIB	European Investment Bank
EPC	Energy performance contracting
ESCO	Energy service company
EU	European Union
FBOOT	Finance Build Own Operate Transfer
IIR	Internal rate of return
O&M	Operation and maintenance
PFI	Private Finance Initiative
PPP	Public private partnership
RE	Renewable energy
RES	Renewable energy sources
ROI	Return on investment
SBICs	Small business investment corporations
WACC	Weighted average cost of capital
WB	World Bank

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1 Introduction

This report provides guidance to facilitate the deployment of improved business models and innovative financing schemes for mobilising investments in small modular RE district heating and cooling systems. It provides information and key parameters for the actors in the sector and represents the basis for the development of individual business models for the target communities in the CoolHeating project.

The main goal of this report is to support capacity building actions in order to mobilise investments in innovative and mature renewable energy systems for heating and cooling. Emphasis is placed on the support of actors and target groups with low awareness and limited knowledge about ownership and business models, who intend to develop projects and to invest in or to finance DHC projects. Local authorities are frequently interested in new DHC projects utilising local or regional RES. Very often they do not possess knowledge or qualified personnel to provide even basic estimations of investment costs, financing possibilities and economic impacts for such projects. This document provides the necessary information for these target groups to evaluate potential investments in DHC projects, to setup possible financing structures and to evaluate basic business models.

The report is closely linked to other reports of the CoolHeating project: For example, the "Handbook on small modular renewable district heating and cooling grids" includes detailed descriptions on the technologies. Furthermore, a dedicated economic calculation tool is being developed in order to calculate the economic feasibility of a project. Using the economic calculation tool, stakeholders can expand on the information available in this report and prepare basic business model calculations, tailored to their potential DHC project. The aim of these activities and deliverables within the CoolHeating project is not to provide detailed business model content and economic lessons, but rather to support actors with information, assessments and tools to build their capacity for the developing of local DHC projects as well as to support competent decision-making and setting of procedures for the potential DHC projects. Detailed assessments and business plans can then be prepared in steps to follow, by specialists.

The document consists of a general introduction and overview of the impact of framework and other border conditions on business models, followed by a brief overview of technological specifics and an outline of investments in potential DHC projects. This is followed by guidelines on potential ownership models and financing options. Business models for DHC projects are complemented with a guide on revenue and cost management with emphasis on contractual guidelines. The structure of the document represents the key parts of a business model represented in a comprehensive and accessible way. Tools and templates to support development of business models are available, like the comprehensive business development template Business model canvas[1]. There are also tools available for specific parts of business models e.g. technical and/or economic assessment tools like the energyPRO[2] or HOMER[3] or tools for heat mapping and planning like the Pan-European Thermal Atlas from the Stratego project[4], PLANHEAT[5] and Plan4DE[6] tools. More information about heat planning tools is available in the Guidelines for initiators of small heating-cooling grids[7].

DHC projects have significant benefits when compared to individual heating solutions. Collective solutions on heating and cooling can provide lower costs for consumers and

[1] en.wikipedia.org/wiki/Business_Model_Canvas
[2] www.emd.dk/energypro
[3] www.homerenergy.com
[4] stratego-project.eu/pan-european-thermal-atlas
[5] planheat.eu/the-planheat-tool
[6] plan4de.ssg.coop
[7] www.coolheating.eu

increasing heating comfort, provide efficient options for heating and cooling using renewable energy sources or waste energy and can help mitigate climate change. Broader impacts of DHC project include also facilitation of local development by fostering local economy chains (e.g. biomass supply), stimulating local employment and stimulating new economic developments (e.g. new business utilising cheap energy).

History has provided us with a wealth of definitions and notions on what business models are. In its core, a business model is a view on the business as a system. It provides critical parameters on how an investment will make money to survive, develop, and grow[8]. Such systems become increasingly complex when including parameters as environmental impacts and social acceptance. Especially for small RES driven DHC projects, environmental and social impacts are important parameters. If environmental impacts are mainly connected to the reduction of carbon emissions, social impacts are connected to local energy supply, facilitating local economic chains and innovative ownership models and especially in models which translate profits into low heat prices. Described measures and guidelines contained in this document will contribute to promote investment opportunities and corresponding business models in order to boost the market uptake of small modular RE district heating and cooling systems in the CoolHeating target countries and beyond.

In general, district heating and cooling involves simple business models, identifying the core business logic as producing cheap heat and then efficiently distributing it to the customer. Based on the homogeneity of the product, few parameters beyond accessibility and price are considered as competitive attributes. On a deregulated energy market, DHC has become just one among many heating options, which compete in price and reliability, and also through more subjective and abstract values such as service quality, environmental impacts and social acceptance. These factors are not easily translated into simple comparison of price. Also the pricing itself can have an influence on the attractiveness of an alternative due to what type of price model is being deployed.

However, DHC supply does not only produce value. Unwanted waste and other types of negative externalities (ash, fossil emissions, negative impact on jobs related to individual central heating of objects e.g. chimney sweep,…) also have to be considered. As we are concerned with the longevity of society and DHC companies, we must include a much more sophisticated long-run perspective on the DHC business models. In the long run, business survivability is not only dependent on value creation, but also on the continuity of the very context in which it is based. The outer limits of a DHC project are defined by the environmental ecosystem of which it is a part of. Thus, many argue that firms should aim for value creation that is ecologically as well as socially sustainable.[9] It is thus important for DHC companies that the processes which they utilize in order to produce value do not produce externalities that in the end will hurt itself. Firm survivability is thus dependent on what value is created as well as how it is created. A number of factors initially define a simple business model: framework and other border conditions, technology used, ownership model. Furthermore, dynamic changes in the energy and technology markets, as well as the adaptation of national framework represent a challenge which innovative business models can tackle in order to produce better economy and consumer experience. The electricity price, for example, is determined by the demand and supply. In periods when supply of electricity largely surpasses needs, electricity prices on the power exchange market will be low, even negative. While in times of high demand, prices are higher. Innovative business models can exploit this development and utilise energy price fluctuations to optimise energy supply to end user in a DHC.

In modern settlements also different groups of energy consumers, producers and prosumers (both producers and consumers) can be identified. Prosumers within the district are assumed

[8] Lee, G. K. and R. E. Cole. 2003. Internet Marketing, Business Models and Public Policy. Journal of Public Policy and Marketing 19 (Fall) 287-296.
[9] www.fjarrvarmensaffarsmodeller.se/pdf/conceptual.pdf

to have a certain amount of flexibility in their consumption and production of energy. This flexibility is a new aspect in the energy market and it can be incorporated into new, innovative business models in order to tackle the barriers for erecting new small modular DHC systems utilising renewable energy sources. The table below represents some of the financial, economic and market barriers for small modular DHC projects utilising RES.

Table 1. Financial, economic and market barriers for renewable energy.[10]

Economic/market barrier
RES not cost-competitive under current market conditions (high capital costs, unfavourable market pricing rules, subsidies for competing fuels, long reinvestment cycles of building-integrated technologies etc.)
Limited access to finance/high cost of capital due to high perceived risk
Favourable power purchase agreements are difficult to obtain
Power markets are not prepared for renewable energy (lack of access to the power markets, exercise of market power by large players, design not favourable for supply-driven RES, etc.)

[10] The table is derived from the Description of market needs and business models in area of district level energy services report of the E-HUB project (Seventh Framework Programme, 2012).

2 Understanding risks before deciding to invest

Before an investment decision is made, the related risks must be understood and evaluated in order to determine the "price", usually expressed as interest rate of the investment. The following risks may occur:

- Perceived lack of experience and knowledge of DHC
- Concerns about potential redundancy of the distribution network in the long-term if alternative technologies were to become more competitive
- Barriers to accessing risk and loan capital if the forecast of the financial viability is difficult
- Lack of familiarity with the concept of district heating amongst consumers and the public sector
- Legislative barriers – complex procedures, time consuming process to feed-in tariff grant
- High investment costs and time-demanding realization
- Impact of the supply and prices of the fossil or renewable fuels
- The complex management of modern systems (purchase of energy/sources and sale of energy), the need for a competent manager

Building of DH plant and distribution network *per se* is not a special or demanding undertaking. However, district heating business models involve specific risks. Some sources indicate that district heating is likely to return less income and create more uncertainty than other large scale investments[11]. There is a lack of experience of DH, which coupled with the sometimes lengthy payback period means that there are few investors willing to consider district heating projects. The main risks are connected to the construction and especially operation of the DH.

Technology risks are relevant to potential investors when a technology is relatively new. The potential risk relates to the confidence that a technology is sufficiently developed and tested to operate on a large scale over a long period. There are different technology options for DH projects and there are robust, proven and extensively used solutions to allay the concerns about technology. However, for countries where DH technology is not extensively used, it is important to develop understanding, using the proven experiences of existing networks to demonstrate the established nature of DH technologies.

Regarding the high upfront capital costs, the construction risk is important. In typical investments the construction risk is managed by turnkey arrangements or similar arrangements where the constructor takes on the risk and requirement to deliver the project to pre-agreed specifications, on an agreed timetable with financial penalties for any failure to meet these targets, thereby insulating the investor from construction risk. An alternate option is to use insurance cover over the construction risk. This is a viable solution, but it includes significant additional costs.

In DH projects, a large challenge is the off-take risk. In order to procure the investment, the revenue flow has to be as secure as possible. It is therefore important to size the DH system appropriately in order to meet the demand of the initial base load, but on the other hand to allow opportunities for grid extension. This is a very complex process and a risk to manage. Depending on the project, it may be a challenge to secure commitments from residential, public and industrial heat consumers to switch from current heating systems to the DH

[11] www.poyry.co.uk/news/potential-and-costs-district-heating-networks-report-decc-poyry-energy-consulting-and-faber-maunsell-aecom

project. It is advisable to focus the base load on most dense populated regions, large public objects (municipal buildings, hospitals, offices, etc.) and industrial clusters, secured by long-term off-take contracts and to focus grid routes on those consumers.

Reducing the off-take risk in relation to private housing, customers can involve high marketing risks and substantial inertia to overcome. One mechanism to tackle this risk is through increasing the cost competitiveness of the DH. It is possible to motivate potential consumers with environmental aspects and aspects of strengthening of local economy. This has been successfully implemented e.g. in Güssing, Austria, where initial connection fees for connecting individual households were relatively high. However, there was significant effort invested from the local authority in order to convince the household to connect to the DH grid as the predominant decision factor for households is the cost. Also Danish experiences show that a key success factor in many DHC projects was a very strong presence of the person or a group of persons which acted as the flagbearers for the planned project. They were willing to bring in significant efforts in the planning stage of the project in order to raise awareness and explain the benefits of such undertaking for the whole community. Households perceive costs related to DH system heat supply through energy price and attachment fee. In many occasions it has been shown, that:

- The connection fee is a very important factor and should be minimised, if possible even covered by the investor and included in the heat price. Some national frameworks foresee grants for RES DH projects which finance also a share of the heating stations. This may be used in financing household connections and also for marketing purposes. It is also important to note, that attachment fees can represent owner share in cooperative models, where consumers are also investors and owners of a DHC project.
- The heat price should be at least on the level of the fossil generated heat cost available in the area covered by the DH. This means that it is easier to convince consumers in areas where more expensive heating oil is available than in areas where also cheaper natural gas is available. A fixed heating price for customers (e.g. contractual or guaranteed savings in comparison to fossil fuels (e.g. the DHC project guarantees 10% lower prices than in heating via heating oil) are also viable options especially in CHP systems where electricity sold partly mitigates the risk of increasing fuel price (electricity feed-in tariffs in some frameworks are being annually adapted to input fuel price change, e.g. Slovene framework). Another option is to dynamically adapt the DH heat price to guarantee competitiveness versus fossil fuel alternatives. Heat price is an important factor to mitigate the risk of consumer switching.
- Private housing consumers rarely have knowledge and awareness to understand the data on the fixed and variable part of the energy price from a DH system. It is important to calculate the total annual price for a representative household in communication and marketing efforts (e.g. public meetings and brochures). And it is important to provide transparent and easy to understand annual heat price comparisons of DHC and alternatives. It is important to consider all annual costs including maintenance, chimney-sweeping services, even amortisation of the investment in an individual heating system.

National, regional and local spatial planning authorities could also define DH zones as the locations where all buildings must be connected to the DH network.

Maintenance of DH systems is also a risk factor, which is managed through long-term contracts, potentially with the original constructing company. An important risk factor is also the fuel price and availability. There were some dramatic fuel price and availability changes in last decade. There are heating technologies that are aimed at lowering the fuel dependency such as seasonal storage and use of solar energy. Some technologies also have some natural hedges. For example gas-fired CHP has a natural hedge between its input fuel price, the cost of the conventional alternative and the expected electricity sale price. During the operation of the project long-term supply contracts are used in order to minimise fuel supply risk. Especially in solid biomass markets contingency should be planned in order to minimise risk of fuel shortage. In markets with high or rising demand for solid biomass it is necessary to have backup suppliers.

Another, more contemporary and innovative option for mitigating risks is also unlinking DH revenues from the delivered (heat) volume. Introducing the availability payments for example may be an alternative way of mitigating the risk for the private investor – with the public sector assuming that risk.[12]

The section above highlights the potential problems associated with constructing and operating a DHC project from the perspective of an investor. The importance to a potential investor is that each of these factors will have an impact on the return they are able to get from a project. Thus, it is crucial for the potential investor to understand and to closely examine all those risks, which implies that the most important phase of any DHC project is the planning phase as the project realization as well as its quality and sustainability depends directly on the properly undertaken project planning. Therefore, it is important to investigate how these risks influence the potential performance of the project and that the investor looks at his business case from a dynamic perspective, employing appropriate tools in order to investigate how changing revenues, costs and heat load impacts on the overall return to an investor. The figure below shows an example of dynamic view on the project performance in the planning phase - the sensitivity analysis of the impact of fuel price and heat price on the payback time / internal rate of return. Sensitivity analysis can be conducted using different parameters of a business model, also investigating impact of e.g. connection rate or even heat prices from different technologies on economic performance of a project.

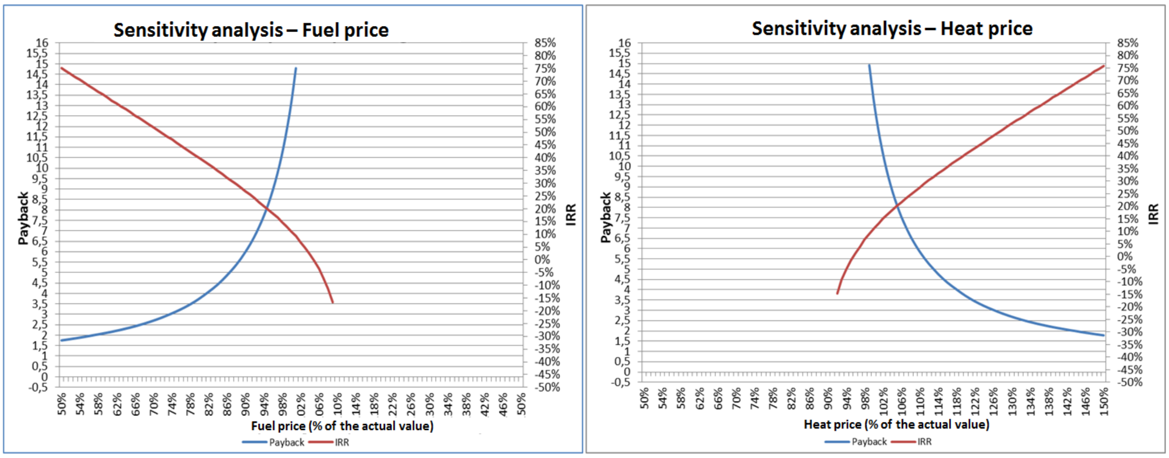


Figure 1. Effect of changing costs and heat prices (deviation from the planned value) on the project performance.

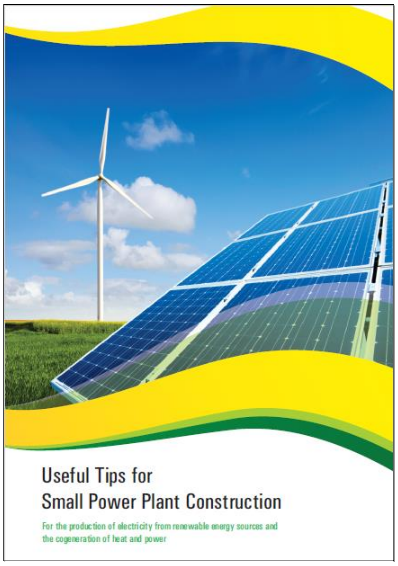
[12] The Potential and Costs of District Heating Networks www.poyry.co.uk

3 Framework conditions

How to start when an idea for an investment into a DHC project in a settlement or a city emerges? Of course, it is necessary to assess the energy demand to be covered and what technology to be used to cover that need in an optimal way. But it is crucial to initially assess what the conditions for a successful investment/realisation of a DHC project are. Framework conditions represent the "rules of engagement" for planning, erecting and operating of DHC projects. They are represented by a set of rules and conditions that are defined in national documents – energy law and energy related acts, decrees etc., and also at the local level, in documents such as municipal or regional energy concepts and decrees on thermal energy supply. They define critical aspects of DHC projects – from who is entitled to invest into a DHC project and in what form this investment can be implemented, what area the investment could or must cover. Moreover, in some cases the framework conditions prescribe even the resources to be used. In this sense framework conditions have the key impact on the layout of the DHC project to be developed and thus on the feasibility and the economy of the project *per se*. They can also have a significant impact on the complexity and time demand of the development of DHC projects. It is not surprising that a lot of national and EC strategies are aimed at lowering the complexity, and time needed for procedures and bureaucracy.

Multiple ownership models exist for district heating networks, ranging from full state or municipal ownership, long term concession agreements with private operators for heat generation and distribution, "unbundled" networks with separate ownership of different network assets or a private owner/operator that bills and interacts directly with consumers and cooperative/consumer owned projects. What models are possible in specific country and what are the required procedures is specified in the national legislation. Ownership models are described in the chapter 4 on Ownership models and financing. Framework conditions for Austria, Germany, Denmark, Bosnia and Herzegovina, Croatia, Macedonia, Serbia and Slovenia are described in the CoolHeating reports Framework conditions and policies on small district heating and cooling grids on the CoolHeating project website[13].

3.1 National guidelines and border conditions



National authorities frequently provide guidelines which provide summaries of regulations and requirements, potential subsidies, stimulations and other parameters needed for preparation of feasibility studies and business plans. Available national guidelines for target and best practice countries are collected below (some documents are available only in national language):

Denmark:

- Danish Energy Agency portal with key information and guideline documents https://ens.dk/en/our-services/projections-and-models/socio-economic-assesments
- Guidelines from the Danish Energy Agency to support the procedure of elaborating descriptions of a project https://ens.dk/sites/ens.dk/files/Analyser/vejledning_2005-rev2007.pdf

Germany:

- Web portals of BAFA- Federal Office for Economic Affairs and Export Control (http://www.bafa.de) and KfW- Kreditanstalt für Wiederaufbau (www.kfw.de) offer

[13] www.coolheating.eu/

information and support on framework conditions and requirements for new DHC projects

- A guideline from BAFA - Federal Office for Economic Affairs and Export Control explains the conditions to receive BAFA support http://www.bafa.de/bafa/de/energie/kraft_waerme_kopplung/publikationen/merkblatt_waermenetze.pdf
- A list of conditions for receiving support by the KfW https://www.kfw.de/inlandsfoerderung/Unternehmen/Energie-Umwelt/Finanzierungsangebote/Erneuerbare-Energien-Premium-%28271-281%29/
- A short guide on DH project development and procedures in Rhein-Hunsrück-Kreis https://www.kfw.de/inlandsfoerderung/Unternehmen/Energie-Umwelt/Finanzierungsangebote/Erneuerbare-Energien-Premium-%28271-281%29/
- Guide on business models for citizens energy cooperative s https://www.energieagentur.rlp.de/fileadmin/user_upload/Buergerenergiegenossenschaften_Broschuere_160210_Small.pdf

Austria:

- Austrian Energy Agency portal with key information and guideline documents https://www.energyagency.at
- District heating portal of Austria with various useful documents and best practices http://www.fernwaerme.at/

Croatia:

- The Environmental Protection and Energy Efficiency Fund web portal with information on national grants for DHC projects http://www.fzoeu.hr/
- The program of utilising the potential for energy efficiency in heating and cooling for the period 2016 – 2030 in Croatia https://ec.europa.eu/energy/sites/ener/files/documents/DOC_88244.pdf
- The web portal of the Croatian energy agency with information on legislation and regulation https://www.hera.hr

Slovenia:

- Energy Agency of Slovenia portal with useful guides and information on heat supply and subsidies https://www.agen-rs.si/web/en
- Slovene Power Market Operator holds information on feed-in tariffs for CHP projects https://www.borzen.si/en/
- A guide on Power Plant construction (including CHP plants) https://www.borzen.si/Portals/0/EN/CP/brosura_v2013_english_FINAL_WEB1.pdf
- An overview of legislative procedures http://www.energetika-portal.si/fileadmin/dokumenti/podrocja/energetika/shema_ove_spte/shema_eng_2013.pdf

Bosnia and Herzegovina:

- Regulatory Commission for Energy of entities in Bosnia and Herzegovina - portals with key parameters on feed-in tariffs, methodology on subsidy calculation and tariff proceedings http://www.ferk.ba/ and http://www.reers.ba/
- The operator for RES and of the subsidy system http://operatoroieiek.ba/

Serbia

- The portal of the Ministry of Mining and Energy of Republic of Serbia / Sector for Energy Efficiency and Renewable Energy holds key information on the relevant legislation and guidelines http://www.mre.gov.rs/latinica/dokumenta-efikasnost-izvori.php

- Guidelines for investors into RES (Electricity only) http://www.mre.gov.rs/doc/efikasnost-izvori/Vodic%20za%20OIE%202016.pdf
- Guidelines for investors into solar heating systems http://www.mre.gov.rs/doc/efikasnost-izvori/Thermo Solar Plants - Detailed Guide.pdf
- Portal of the Biomass related portal with elaborate guidelines for investors http://biomasa.undp.org.rs/?page_id=984&lang=en

<u>Macedonia</u>

- Energy regulatory commission of Macedonia – web portal with key national legislation documents and procedures on licencing and monitoring, includes overview of the legislation and required procedures http://www.erc.org.mk
- Guidelines on required procedures for CHP projects http://www.ea.gov.mk/index.php?option=com_content&view=article&id=205%3A2011-09-09-12-10-38&catid=44%3Aza-agencijata&Itemid=130&lang=mk
- Guidelines for energy efficiency, production and use of energy from renewable sources in agriculture http://www.ea.gov.mk/index.php?option=com_content&view=article&id=1392%3A2012-07-23-13-23-47&catid=35%3Aactivities&Itemid=130&lang=mk

National regulations define key critical parameters DHC projects have to reach or include. These are critical parameters projects have to consider in order to comply with national regulation, receive additional revenues (e.g. feed-in bonus for biogas plants when utilising waste heat) or even receive subsidies at all. These requirements frequently include the following key parameters:

- General concept of arranging the responsibilities and tasks – national regulations define whether and in what form the DH energy can be sold and supplied to consumers, whether it can be a form of public private partnership (PPP) or a private investment (ESCO – energy service company).
- Minimal efficiency – CHP plants fuelled by a solid biomass often have to achieve a minimal required overall energy conversion efficiency of biomass into electricity and/or mechanical energy and useful heat, during the reporting period or within one year, to be eligible for support. For example, regulations in Slovenia require 60% overall efficiency under Regulations of the Decree on support for electricity produced from renewable energy sources.
- Minimal DH grid heat density – e.g. minimal grid heat density for DH projects in Slovenia in order to win entitlement for national grants is at least 800 kWh/m per year.
- Maximal allowed emissions. National regulative defines the maximal allowed emission of DH/CHP plants. The national Decrees on limit values for emissions into the air from large combustion plants define maximal allowed emissions of NO_x, CO, SO_2 and also dust.

National agencies or competent ministries issue methodology on calculation of parameters set by the framework. It is important to consult documents describing the methodology and if needed also to consult the agencies or the competent ministries in order to explain the methodology. As mentioned in the previous paragraph, some national decrees define minimal annual efficiency of CHP projects in order to receive the feed-in tariff. Methodological details explain how overall efficiency is calculated. In some frameworks heat produced in a DH plant can be used for drying own biomass/fuel and the heat employed for drying can be included in the overall efficiency calculation. There are limits to the amount or proportion of the produced heat used for biomass drying that can be included in overall efficiency. But this measure can help a project to reach the required overall efficiency. Details in methodology also reveal exact measurement of own electricity use of CHP plants etc. Investors should keep in mind that most CHP projects are only feasible by selling the heat and not wasting the heat (e.g. drying). That's why it is important to have enough heat consumers. Otherwise there is still the option not to realize the CHP at that location.

3.2 Framework conditions – subsidies/grants

Framework conditions reflect the vision of development of the energy sector in a given country at a given time period. A country with abundant biomass supply will most likely provide framework conditions that will enhance economic effectiveness of biomass driven DHC projects. But at a certain point, when the amount of end energy produced from that source reaches the targeted value framework conditions can change. This can render good projects economically unviable. Therefore, it is important to understand the framework conditions as an on-going process within a time period and not a static set of rules. In some cases changes of the framework do not catch up with the development or needs of the energy market and in some cases drastic change of framework conditions utterly changes the energy landscape.

Highly developed countries show a development into diversification of the supply of DHC networks. Different technological options using different energy sources (e.g. biomass plant combined with natural gas CHP combined with electrical boilers/heat pumps or solar energy) enable DHC plants to optimise their production according to the lowest energy source cost. It is also visible, that in highly developed countries strong and diversified CHP plants aim at economic stability without using subsidies provided by framework conditions, thus eliminating the possible drastic changes in the business environment.

Governments of EU countries use various market based instruments to provide incentives and to subsidise renewable energy. These can be divided into two groups:

- **Investment support** - capital grants, subsidised loans or "soft loans", national guarantees, tax exemptions or reductions on the purchase of goods.
- **Operating support** – feed-in tariffs, price subsidies (for power or also for sold heat), green certificates, tender schemes and tax exemptions or reductions on the production of electricity or heat.

In general, the operating support (bonus per produced MWh of energy) is seen to have more significance than investment support. This type of support is more frequently available for production of electric energy; however, there are cases where this type of support is available also as a subsidised heat price. A typical investment uses a combination of support schemes to realise renewable energy investments. As an example, a common combination of support schemes is to have investments subsides or soft loans in addition to the support scheme, such as feed-in tariffs or quota obligations.

Quantity-based market instruments:

- **Quota obligation** – Governments/regulators/authorities impose an obligation on consumers, suppliers or producers to source a certain percentage of their energy from renewable sources. This obligation is usually facilitated by tradable green certificates. Accordingly, renewable electricity/heat producers sell the energy at the market price, but can also sell green certificates, which prove the renewable source of the electricity. Suppliers prove that they reach their obligation by buying these green certificates, or they pay a penalty to the government.
- **Tendering** – Governments/regulators/authorities announce a tender for the provision of a certain amount of energy from a certain technology source, and the bidding should ensure the cheapest offer is accepted.

Price-based market instruments:

- **Feed in tariff and premium**: Feed-in tariffs and premiums are granted to operators of eligible domestic renewable electricity plants for the electricity they feed into the grid. The preferential, technology-specific feed-in tariffs and premiums paid to producers are regulated by the government. Feed-in tariffs take the form of a total price per unit of electricity paid to the producers whereas the premiums (bonuses) are paid to the producer on top of the electricity market price. An important difference between the feed-in tariff and the premium payment is that the latter introduces competition between producers in the electricity market. The cost for the grid operator is normally covered through the tariff structure. The tariff respectively the premium is normally guaranteed for a period of 10 – 20 years. In addition to the level of the tariff respectively the premium, the guaranteed duration provides a strong long term degree of certainty which lowers the market risk faced by investors. Both feed-in tariffs and premiums can be structured to encourage specific technology promotion and cost reductions (the latter through stepped reductions in tariff/premiums). This instrument is usually applied for production of electric energy. However, the principle can be applied also for sale of heat energy and could represent an important support scheme for small modular district heating and cooling projects. Small DHC projects frequently cannot achieve as low heat prices as large projects and projects which include CHP technologies. Subsidised heat price could help them achieve competitive heat price for end consumers, providing significant motivation for potential DHC consumers.
- **Fiscal incentives**, (e.g. tax exemptions or reductions): Producers of renewable electricity and/or heat energy are exempted from certain taxes (e.g. carbon taxes) in order to compensate for the unfair competition they face due to external costs in the conventional energy sector. The effectiveness of such fiscal incentives depends on the applicable tax rate. In the Nordic countries, which apply high energy taxes, these tax exemptions can be sufficient to stimulate the use of renewable energy; in countries with lower energy tax rates, they need to be accompanied by other measures.

National framework conditions are the fundament of development of successful DHC business models. Municipal governments play a central role in addressing the risks (actual and perceived) and costs associated with investing in DHC systems. Local governments are enabling and easing access to low-cost finance in order to stimulate private investment and industry activity. Local governments ranked the public sector as the “most important” actor to catalyse investment in DH, particularly in new schemes. The private sector was ranked as “very important” in catalysing investment, primarily through the provision of technical and operational support.[14] There are different activities that local governments can undertake in order to stimulate investments into new DH projects.

[14] District energy in cities: Unlocking the potential of energy efficiency and renewable energy”, Global district energy in cities initiative. UNEP www.unep.org/energy/portals/50177/DES_District_Energy_Report_full_02_d.pdf

Table 2. Policy activities that local governments are undertaking in their role as facilitator

Policy intervention area	Description of policy activity
Financing and fiscal incentives	• Debt provision and bond financing, loan guarantees and underwriting, city-financed revolving funds
	• Grants, low-cost financing/loans, rebates, subsidies
	• Tax credits and exemptions within tax systems; for example, sales, property taxes, permitting fees and carbon taxes
City assets	• Use of local government land/property/buildings for district energy installations or connections, or for anchor loads (leasing/selling/permitting)
Demonstration projects	• Piloting and testing emerging (often hybrid) technologies, such as low-grade waste-heat recovery from sewage or metro, and renewable energy integration and storage
	• Piloting new policies for DHC systems

4 Technology and investment

DH is often characterized as a homogeneous industry due to the impossibility of diversifying the product – the hot flowing water. Despite this the industry is remarkably heterogeneous when it comes to with what technology this hot water is produced and how delivery is conducted. Diversification is also one factor that plays a key role in the strategic processes for many district heating companies, with all developments in the sector, it makes more proper to denote these firms as energy companies rather than district heating companies. The cost-competitiveness of renewable power generation technologies has reached historic levels.[15] As can be observed from the table below, electricity from biomass, hydropower, geothermal and onshore wind can all provide electricity competitively compared to fossil fuel-fired power generation.

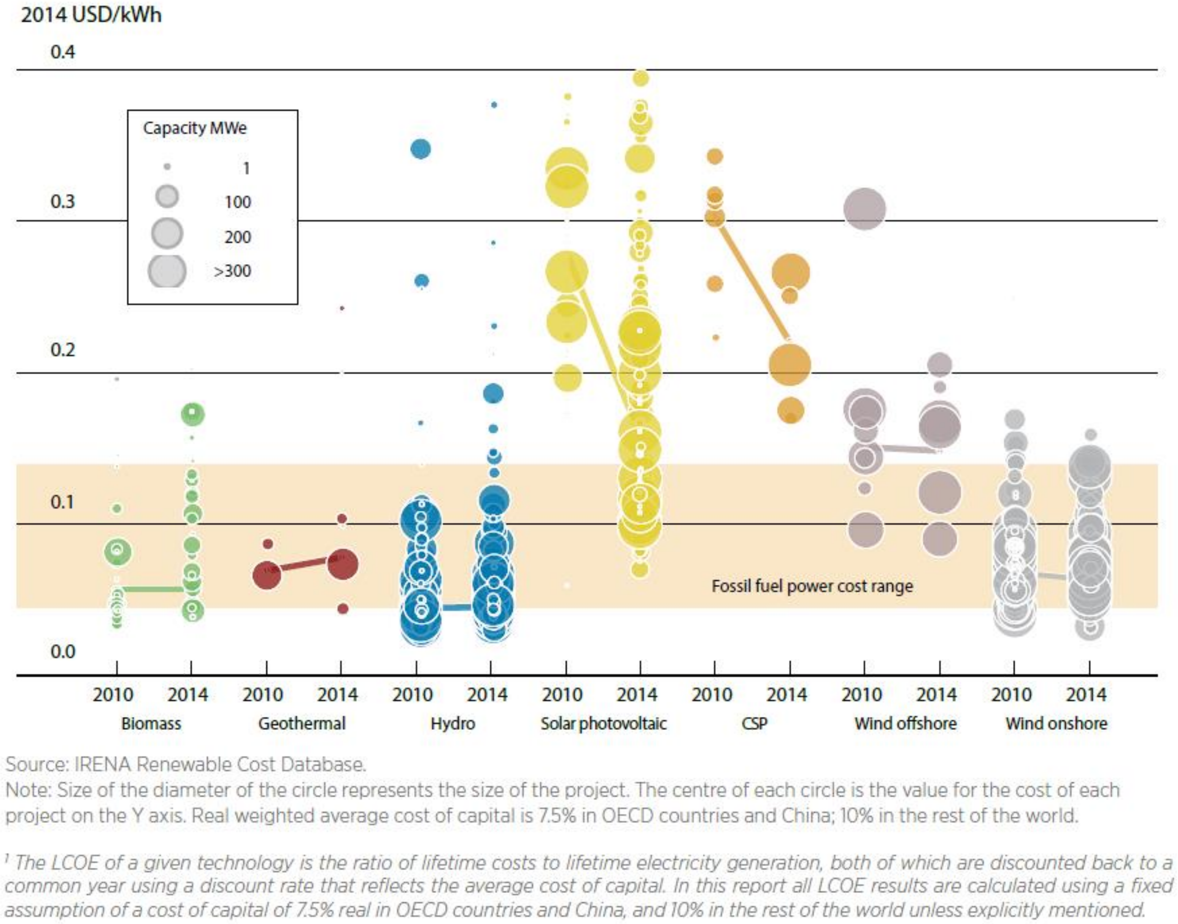


Figure 2. The levelized cost of electricity from utility-scale renewable technologies, 2010 and 2014, IRENA Renewable Cost Database.

DH has a high potential and is in focus of EU development strategies. DH provides 9% of the EU's heating[16] in 2012 with natural gas as the main fuel (40%), followed by coal (29%) and biomass (16%). DH can integrate renewable electricity (through heat pumps and electric boilers), geothermal and solar thermal energy, waste heat and municipal waste. It can offer flexibility to the energy system by storing thermal energy, for instance in hot water tanks or underground. Single small modular DHC grids can be fed by different energy sources, include different technologies, utilise a specific solution/module for a specific time period or a

[15] IRENA Power Costs 2014 Report www.irena.org/
[16] ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v14.pdf

specific season. Resources used, technologies deployed and synergies provide one of the key elements in planning of DHC projects and developing business models.

If the planning process is done in a sustainable way, small modular district heating/cooling grids have the advantage, that at the beginning only part of the system can be realised and additional heat sources and consumers can be added later. This modularity requires well planning and appropriate dimensioning of the equipment (e.g. pipes). It reduces the initial demand for investment and can grow steadily.

A survey in Sweden[17] has shown that the size of the DHC project dictates the consumer energy price. It has also shown that in general companies with higher heat prices have failed to include CHP technology with added revenues from electricity production. In general, companies with higher heat prices also depended more on bio- and fossil fuels, than less expensive companies who use more waste and industrial waste heat. In the study this also translated in lower profits for more expensive DH companies even at the higher consumer price. It is important to add, that in that study it was shown that the firms with a fuel mix dominated by biofuels were the most expensive followed by industrial waste fuel and then waste. It has also been shown that the companies with fuel mixes dominated by biofuels seemed to suffer the most from rising input prices. As DHC companies in developed countries are developing into energy companies it is important that they frequently develop a differentiated set of technologies applied and fuels used, capitalizing from economically most efficient options in specific time periods or seasons. This implies that efficient business models for DHC projects are flexible systems which can adapt to changes in the market also using different technologies and solutions that are maybe more expensive in short term (e.g. biomass DH including solar technologies and large storage capacities) but which enable more flexibility and less dependence on fuel price. And they will have to be flexible while facing challenges in order to be competitive in the future as low and passive energy constructions will become common practice, new services (e.g. smart metering of heat) and pricing systems, financing models and new technologies like hybrid heating systems are requested by the markets.

For small modular renewable district heating (DH) grids, various technologies are available, which are mature and commercially viable. There are also technologies which are not market ready and can be implemented as pilot projects. It is important to underline that these technologies are usually more expensive (although entitled to significant grants for pilot projects) and can represent a higher risk. A good example is the well documented case of the Güssing 2 MW_{el} gasification CHP plant. It was the world's first functioning Fast Internally Circulating Fluidised Bed (FICFB) plant, a pilot project where the investment included significant EU and national grants and a feed-in tariff. The plant in itself is a lighthouse project and an important piece in the Güssing model success story. But it has to be taken into account that it required 3 years of optimisations of the new technology for the plant to go from 40% availability to 90% availability. Such risk of lower full load operation hours and additional costs for operation optimisation and additional maintenance has to be taken into account as it was the case in Güssing, or else it can have serious consequences for the considerable investment into the DHC project. The investment into a DHC project can be broken down to the following segments:

- Planning, feasibility study and project documentation,
- Real estate (land purchase)
- Civil works,
- Technology,
- Heat distribution network,

[17] www.fjarrvarmensaffarsmodeller.se/

- Heat transfer stations.

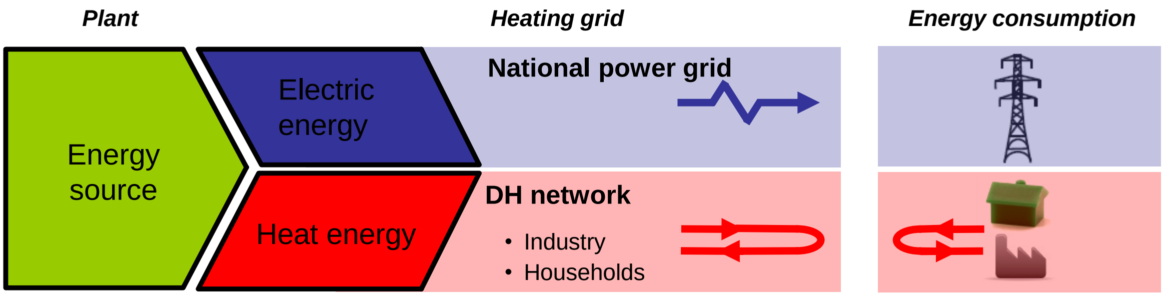


Figure 3. Overview of the DHC project parts. The Heat energy can be used for heating or cooling at the consumer side. (Source: Skupina FABRIKA d.o.o.)

4.1 Planning, feasibility study and project documentation

Planning and feasibility assessments are the key initial activities in a DHC investment. They lay down fundaments for plant erection, technology to be used and assesses its basic economic and environmental impacts. It can happen that the project does not evolve further than to this point if the feasibility study does not show economic efficiency or if environmental impacts are unacceptable (regarding legislation and regarding stakeholder acceptability). Therefore, it is frequently that the feasibility study cost is not included in the overall investment costs and it also poses a very small share of the overall investment. Project documentation on the other hand represents a smaller part of the investment costs and can amount to 4-8% of the overall investment costs. The required project documentation and terminology used depends on the national legislation, usual parts of the project documentation are at least Basic design, Building permit, Reports on the project execution, Process documentation of the implemented work and Operating permit.

In the planning phase it is recommendable to acquire also the planning and spatial information for the location of the DH plant. In the case of a CHP project it is also crucial to obtain the consent from the competent electricity distribution company as to whether it is possible to include the planned production unit in the public electricity distribution network. Planning information is issued by the municipality where the land or building, on which the investor is planning to construct a production unit, is located. It is issued by the municipality in accordance with regulations governing administrative procedures and an administrative fee is charged. Planning information lays down the criteria and conditions for planning the investment as defined by applicable spatial planning acts, the information on safeguards, restrictions and prohibitions from the adopted spatial measures and information regarding changes and supplements or the preparation of new spatial planning acts.

The opinion from the competent electricity distribution company is obtained as to whether it is possible to include the planned production unit in the public electricity distribution network in order to facilitate the planning of the investment input. The electricity distribution company will establish whether a connection is possible with regard to the production unit's type and power and the type of connection (single-phase, two-phase and three-phase), in view of the conditions in the electricity distribution network and the allowed interference that a production unit can cause in the electricity distribution network. This means it will state the basic conditions for the CHP production unit to be connected in accordance with the calculated network parameters and the desired connection method at the investment site.

Planning of small DHC projects is described in detail in the free available Handbook on small modular renewable Heating and Cooling grids handbook[18] and Guidelines for Initiators of Small heating-cooling grids[19].

4.2 Plot and Civil works

Depending on technology employed and project size the erected DHC plant can have significant impact on the urban or rural area in which it is placed. Plants that utilise biomass require constant delivery of biomass, which puts pressure on the local roads. Also woodchip production can have significant impacts on the environment. If a project does not consider urban and spatial planning and if it is planned to be located in an urban area without assessing environmental impacts and citizen involvement, it can pose a significant risk of rejection of the project by the local population. It is therefore important to assess environmental impacts, to work closely with the local and national authorities and to involve the local population in decisions related to the location and environmental impacts.

In general, the costs for land and civil works represent around 15 – 25 % of the overall investment into the DHC project, depending on the labour costs and other economic factors in the country where a project is implemented. The land cost can have a significant impact on the overall costs. It could be a good opportunity for local authorities to support the DHC project with cheap land, low cost land lease or even providing land with zero costs for the investor. Civil works cost depends on the prices in specific country and can vary a lot.

A small 1 MW_{th} biomass DH project requires approximately 3,000 m^2 of a building plot for the heating plant. This plot includes the required land for manipulation with biomass and storage of biomass. A 1 MW_{th} solar plant requires approximately 4,000 m^2 of land for installing of solar collectors.

4.3 Technology

The heart of the investment in a DHC is the technology for generating the required energy from an energy source. There are different energy sources that can be utilised in a DHC project. Usually all small modular RES DHC projects utilise one or more RE heat sources, backup or peak load systems, and process energy (e.g. for pumps, control…).

Past investments and new projects usually focus on one renewable energy source as the core of the project. However, many existing and innovative DHC projects include more RES technologies and optimise their operation accordingly. It is hard for new DHC project to include more technologies as this usually represents considerable additional investment costs. However, combined technologies for utilisation of solar energy with other RES to satisfy the needs for sanitary hot water at least in the summer is often feasible.

The local/regional availability of RES influences the selection of the energy source for a project. Availability has the predominant influence on the economy of the project. E.g. in locations where biomass would have to be transported for hundreds of kilometres, other options might be more viable. In the following chapters a brief overview of available technologies is presented with focus on economic impacts. Additional details about technologies and planning of DH plants is provided in the “Handbook on Small Modular District Heating and Cooling Grids”[20].

The key parts of the DHC system are the energy generating plant and the distribution network. The generalised breakdown of the investment:

- Heat generating plant investment breakdown
    - Electrical components, controls, visualisation

[18] www.coolheating.eu/images/downloads/CoolHeating-Handbook.pdf
www.coolheating.eu/images/downloads/Guideline_for_initiators_small_heating_cooling_grids_2.6.pdf
[20] www.coolheating.eu/images/downloads/CoolHeating-Handbook.pdf

  - Fuel storage and transportation. In case of biomass plants this part of the investment can include also a vehicle for fuel manipulation and loading.
  - Energy generating technology.
  - CHP technology. This part of investment also involves a connection to the power grid. The required infrastructure (power substation) has to be available. If not available this can represent a considerable additional cost.
  - Emission management. Waste air cleaning in case of combustion technologies including potential bag or electrostatic filters, ash transport and storage. It is important to plan also disposal of waste outputs of the plant.
  - Transport, erection, start-up. A turnkey plant erection includes all required transportation and erection work and also a start-up of the plant.
- District heating network
  - Electrical components, Controls, Visualisation
  - District network pipelines. Represent the bulk of the costs of the district heating network. Possible natural (stream, river, stony underground) and infrastructural obstacles (railroad, bridge, dense city centre) can represent significant additional costs for the project.
  - Heating substations and metering and connection

It is practically impossible to provide an investment cost guide for a typical DHC project. The investment cost varies depending on technology used, especially if the project is focused on single RES or if the plant includes more technologies/resources. The DH grid includes even a higher variability of investment costs. A distribution network connecting a large amount of consumers will include significantly higher costs than supply of a single large industrial consumer. DH grid crossing obstacles as rivers, railroads etc. can also significantly increase investment costs. In general, a simple 1 MW_{th} DH project utilising biomass, even complemented by solar energy (not including CHP) can be erected for approximately 1 to 2 M€. Including district cooling will significantly increase investment costs.

4.3.1 Solar technologies

Solar thermal technologies utilise energy from solar radiation and produce useable heat for central heating and domestic hot water. Typically, water is heated by arrays of solar thermal collectors. For district heating systems, the collectors are often installed on the ground in long rows connected in series, and in smaller systems the collectors are also installed on roof tops. The investment in larger-scale solar technologies includes acquisition of required land (which represents the major part of the investment cost as a lot of land is required for bigger systems) for the collectors and preparation of that land to suit the technology.

There are many suppliers of solar collectors on the market in Europe. Solar thermal collectors are a mature technology, which now enter a phase of large-scale applications, further decreasing the investment costs and thus increasing the feasibility. Good installed solar collectors can even work when the outside temperature is very low. District heating systems equipped with solar heating usually need also other technologies (heat generators and seasonal storage) in order to ensure continuous heat supply.

It is a robust technology with a long technical lifetime (25-30 years) and low maintenance cost (0.7 € per produced MWh heat), low electricity demand and low personnel demand. The heat production price is not sensitive to variable costs of fuel. The technology has high initial investment costs per MW but with a depreciation period of 15-20 years, the heat production cost is competitive with e.g. biomass based heat production. There are specific requirements regarding the locating of a solar DH plant. The land should not be shadowed and has to provide enough space for collectors. Also, a good orientation and inclination is preferable (orientation to the south for Europe, and inclination depends on latitude). For 1 MW_{th} of solar thermal capacity more than 1,250 m^2 of solar collectors are needed, which require more than 4,000 m^2 of land.

4.3.2 Biomass systems

Biomass is the organic matter created by living (plant material, humans and animals and their excreta), or recently living organisms. It also includes secondary products when biomass is used, such as bio-waste, paper, wood products, etc.[21] Biomass is a very widely used energy source for small district heating grids. The main advantage is its storability and its utilisation on-demand. For example, wood can be stored for a long period until its heat is needed in winter. This is a main difference to fluctuating renewable energies such as solar and wind, which are more difficult to store. Thus, the combination of a biomass system with a solar system has the potential to maximize synergies.

While utilising technologies for solid biomass (woodchips, pellets, logwood, agricultural residues) it is important to consider the water content and quality of the biomass. Good quality fuels can be used in any system, but very low quality fuels may be used only in selected systems, that are usually larger systems and have special equipment. The water content in fuel has to be taken in consideration while purchasing solid biomass. It is strongly recommended to calculate biomass price based on heating value and not based on raw volume or mass purchased. E.g. one kilogram of beech wood with water content of 50% has less than half of the heating value of one kilogram of beech wood with 15% of water content.

Solid biomass, such as wood chips or pellets, can be used in boilers of different sizes. Such DHC systems can produce heat only or produce both heat and power (CHP – combined heat and power plant). CHP systems are increasingly implemented. They are more complex and require considerably higher investment, maintenance and operation costs than the systems for heating only. But they provide two outputs, heat and electricity. In countries with price based market instruments (feed-in tariff and premium) revenues generated by sales of electricity usually make use of CHP technologies highly lucrative. On the other hand it is important to consider that CHP technology has significant impacts on the overall project:

- Costs – significant increase in operating cost and maintenance.
- Fuel – significant increase in feedstock required. Addition of the CHP module to the DHC project increases the fuel demand for the same thermal output to district network. When considering local or regional supply with solid biomass, increase in fuel needs can have a significant impact on the logistic of biomass supply.
- Project complexity – in planning and erecting the plant, fuel logistics involved but also in administrative procedures required. Some national legislations also impose efficiency requirements (e.g. 60% overall annual efficiency in Slovenia and 75% annual efficiency in Croatia) for CHP projects. The feed-in tariff mechanisms expire at some time (10 – 15 years). It is important to consider the economy of the project also after the feed-in contracts expire.

The technology for woodchip and pellet heating is mature and provided by many manufacturers. Also CHP technologies are robust and reliable, especially in medium to large size. The most commonly used CHP technologies are steam turbines (for large projects where this technology provides high efficiency), ORC (for mid-sized projects) or even gasification (for smaller projects). More detailed descriptions of technology are available in the Handbook on small modular renewable district heating and cooling grids[22]. CHP can produce significant additional revenues, energy and CO_2 savings compared to separate generation of heat and power.

[21] Adapted from the CoolHeating Handbook on Small Modular District Heating and Cooling, www.coolheating.eu/images/downloads/CoolHeating-Handbook.pdf

[22] www.coolheating.eu/images/downloads/D4.1_Handbook_EN.pdf

4.3.3 Biogas systems

Biogas is produced by anaerobic digestion of organic material. Biogas systems are flexible systems which have been in the past mostly oriented in electricity production through the use of CHP. Heat utilisation was largely neglected but this is being changed. However, there is still a significant amount of heat energy available from biogas in EU for commercial use. National regulations often provide at least CHP bonuses in case a certain level of efficiency is reached, thus at least a part of heat produced is being utilised. Produced biogas in biogas plants has certain flexibility. It can be used in a CHP unit in the plant, it can be transferred to a location where heating is required and used in a CHP unit there or it can even be upgraded to biomethane and injected into the natural gas grid.

Biogas systems are a robust and proven technology. The planning has to take into consideration environmental impacts (fuel logistics, odour). There is a large amount of biogas systems in EU which produce waste heat that is not utilised and could be used for a very small cost, improving the economy and lowering risks of the biogas system as well as providing cheap energy to consumers.

Various organic materials can be used for anaerobic digestion, they are described in more detail in the Handbook on Small Modular District Heating and Cooling[23]. It is important to consider that there are restrictions in place for using some organic material as biogas plant feedstock. There are restrictions in some countries regarding use of material as grains as biogas feedstock as it is not sustainable. It is also important to plan biogas systems close to the feedstock. Usually the most economical and most sustainable plants are ones that are built close to farms or other producers of feedstock.

4.3.4 Geothermal energy

Investment into use of geothermal energy is related to relatively high investment costs. The investment costs depend on the depth of the underground water reservoir. With roughly 1 million € drilling costs per 1,000 m it is clear that it makes most sense to utilise this RES where geothermal energy is available at shallower depths. It is also important to underline that there are considerable risks involved in drilling boreholes of 2-3 km depth, not only due to the drilling itself but also because the water flow may be smaller than planned. Utilisation of geothermal energy is renewable only if the used hot water from the deep is being returned to where it has been taken from. A lot of national legislations require reinjection wells for pumping the used hot water back in the earth. This represents significant additional investment costs and also significant electricity costs for pumping. Additional energy carriers are therefore required to utilise geothermal energy. Even if it is desirable to drill deeper wells for reaching higher temperatures it is frequently more economical to utilise geothermal energy from shallower reservoir due to increased pumping costs for deep wells.

It is also important to consider the properties of the geothermal water for a specific project. Impurities and specific water consistency can rapidly corrode pipes and heat exchangers, producing edictal costs for the project. In general the utilisation of this renewable energy carrier is still rather undeveloped in EU although the technology involved is relatively simple, robust and proven. If carefully planned, the risks can be minimised also with the use of data from an abundance of existing (operated and not operated) boreholes that have been drilled for geological surveys in search for hydrocarbons and geothermal energy in EU.

[23] www.coolheating.eu/images/downloads/CoolHeating-Handbook.pdf

4.3.5 Waste heat and cold

Some industries generate heat as a by-product which could be reused within the DHC plants or sold directly to provide heat for surrounding buildings. The same applies to waste heat from power stations, the service sector and infrastructure. Also waste cold is generated in sites such as liquefied natural gas terminals and gas grids and is rarely reused, although the technology to do so is already used on a commercial basis in some district cooling systems. Integrating the production, consumption and reuse of waste cold creates environmental and economic benefits and reduces the primary energy demand for cold. How a specific industrial energy consumer generates heat and deals with potential waste heat depends on specific individual company/factory. The table below shows some typical parameters of heat used in some industrial sectors and can help in defining potential waste heat utilisation concepts.

Table 3. Typical steam and heat quality requirements of some industrial sectors.[24]

Industry	Sector	Steam and heat requirements		
		Temp (ºC)	Press. (bar)	Form
Agro and wood	Palm oil		3 – 4	S
	Pulp and paper	< 200	Up to 11	S
	Rice mill	110	1.5 – 2	S
	Wood	110 – 150	2 – 5	S / HA
	Sugar	70 – 130	2 – 3	S
Chemical	Plastic sheets and products	< 200		S / HW
	Smoked rubber sheets, blocks, and crape rubber	50 – 70		HA
	Rubber products	< 200		S / HW / HA
	Chemicals, medicine and toiletries	< 200		S / HW
Food	Beverage	150 – 165	5 – 7	S / HW
	Animal feeds	< 200		S / HA
	Vegetable oils, animal oils, fats	80 – 180		S / HA
	Tapioca flour and pellets	< 210		S / HA
	Bread, cookies, noodles	< 180		S
	Milk	140	1.8	S
	Fruit	130 – 180	3, 6, 10	S
	Frozen food, food canning	100 – 225		S
Other	Petrochemical (lube based oil)	140 – 240	2.8, 13.8	S
	Textile	< 270		S

S = Steam HA = Hot Air HW = Hot Water

The utilisation of waste heat and cold can provide access to energy at very low costs. But it also means dependence on the source of waste heat. Therefore, it is important for planning contingency with backup systems or other means to replace the waste heat source. Time-related fluctuations in heat production (storage might be needed) and the temperature level (heat pump might be necessary) should be considered.

4.3.6 Smart combination of different heating technologies

Modern electricity grids are integrating more renewable energy sources, especially wind and solar including decentralised supplies. Supply and demand will thus become more flexible, through wider use of demand reduction, demand response mechanisms and energy storage.

Linking heating and cooling with electricity networks can reduce the cost of the energy system to the benefit of end consumers. Utilising off-peak electricity can be used to heat water in lagged tanks which can store energy for days, weeks and even for longer periods. The integration of different technologies and deploying adaptive operational strategies enables to utilise optimal technologies in specific periods in order to:

[24] Technical Report Available Cogeneration Technologies in Europe, Cogen3, 2003.

- Minimise costs – optimising for reducing the feedstock demand by maximizing the utilisation of cheaper but temporary available RES such as solar thermal energy, which usually also reduces the maintenance costs
- Maximise revenues – optimising for maximisation of CHP electricity production in peak periods and use of electricity to replace other energy sources in negative price periods

4.3.6.1 Power-to-heat

The application of electric boilers in district heating systems is primarily driven by the demand for ancillary services on the electricity market rather than the demand for heat. Hence, the use of electric boilers is usually a supplementary technology, generating cheap heat when electricity prices are low or even generating income when spot prices in the electricity market are negative, thus reducing the heat price. Electric boilers can be a part of the energy system facilitating the utilization of peak-load wind energy and enabling efficient utilization of various heat energy sources.

The technology is simple, reliable and efficient and is implemented in optimisations of existing DHC systems rather than in new projects as it poses a significant additional investment cost. By benefitting of low electricity prices or even negative prices it can pose significant economic benefit to a project both lowering fuel demand and cost and potentially even providing additional revenues.

4.3.6.2 Heat pumps

Integration of heat pumps into solar district heating systems can improve energy efficiency of the solar DH systems. The economic efficiency is depending on electricity price, but alongside decarbonising grid, integrating heat pumps into district heating offers large CO_2 emissions reduction potential.

Due to high investment costs, the price of heat is likely to be significantly higher for district heating schemes incorporating heat pumps. This intensive investment an be mitigated with utilisation of cheap or even negative cost electricity, similar as in the previous subsection. Further cost savings could be achieved by using heat pumps in schemes where both heating and cooling are required. Cooling demand is often a driver for the installation of heat pumps over other technologies in heat network applications. Using heat pumps for both heating and cooling can help increase the thermodynamic efficiency of a system if heating and cooling loads are balanced either instantaneously or seasonally.

4.3.6.3 Storage

Heat storage is an important element for economic efficiency of DHC projects. Storages increase the flexibility to utilize sources of energy that are not available at the same time as the demand. They can also store cheap energy, e.g. low priced electricity that can be converted to heat. Furthermore, storages help to increase the efficiency of production units. They enable for example biomass boilers and CHP plants to operate continuously at maximum capacity thus optimising revenues.

Depending on the time when the heat is needed from the storage, a typical classification is made between short term storages and seasonal storages. Short-term storages balance the heat supply and demand of a few hours or few days. They are also called buffer tanks. Seasonal storages are much larger, as they balance the heat supply and demand from one season to another. This is mainly applied for storing solar thermal heat from summer to wintertime.

4.4 Heat distribution network

The heat distribution network represents a considerable share of the overall investment costs. It depends on the project layout and the location (density of the objects to be connected to the network, possible obstacles like rivers, railroad tracks, etc.). The investment in the distribution network can amount to more than one third and up to one half of overall investment costs of a small modular DHC project.

A distribution network delivers energy carrying media from the heating plant to the consumers. The distribution is not lossless. Typical network losses are in the range of 15-20%. The loss can be reduced to approximately 7% in very large systems like in Greater Copenhagen, Denmark. They can be also up to 50% in systems in very poor conditions (Danish Energy Agency & Energinet.dk, 2015).

The investment costs for DH network depend on the peak load of the network, heat density of the grid etc., but also on the characteristics of the location. In case a river or a stream has to be crossed, or a railroad has to be broken through, the costs can be significantly increased. It is recommended to plan the network route carefully in order to avoid additional costs. It is also possible to plan and to lay DH pipes in synergy with other similar (public) works, such as renovation of roads or laying of other pipes/cables (e.g. communication cables).

4.5 Heat transfer station

The heat transfer station is the equipment that transfers the heat from the DH grid to the consumers. Usually, houses are connected (Austria, Germany) to the district heating grid by using a heat exchanger (indirect system) to separate water from DH and installation of the house. This equipment is located in a heat transfer station at the houses. In Denmark, often a direct system without a heat exchanger is applied. The direct system is cheaper as the required heat transfer station does not include the heat exchanger. On the other hand it poses some risk as the direct system can suffer water losses from within consumer object flaws and in the direct system pathogens such as Legionella from the DH network can enter the domestic sanitary water consumer's use. The owner of the domestic hot water facility is responsible for ensuring health safety.

Depending on the legislation, it may be necessary to install an official calibrated heat meter. The heat meter needs to be calibrated periodically. Usually heating costs consist of costs for the used heat (€/kWh), needed heat peak load (€/kW per month) and metering costs (€/a). More details on heat tariffs are available in the chapter 5 on revenue management.

5 Ownership models and financing sources

In this chapter, the ownership and financing sources of the DHC projects are described. There are various forms of ownership. In a highly developed country as Denmark, the largest plants are owned by large energy companies, while smaller plants are typically owned by production companies, municipalities, or cooperative societies. The selection of the ownership model can have a significant impact on the project realisation and especially on the off-take motivation of the consumers. In well-functioning and connected municipalities and communities cooperative ownership model can be an interesting option. However, the decision on the ownership model depends also on the possibilities to obtain the needed capital to finance the investment costs described in the previous chapter. Furthermore, ownership is closely connected to the potential business models used in a specific DHC project therefore both ownership and business models are described in this paragraph.

5.1 Ownership models

Business models for DHC systems are project specific. A selected and defined business model needs to ensure that all stakeholders – including investors, owners, operators, utilities/suppliers, end-consumers and municipalities – can achieve financial returns, in addition to any wider economic and other (social, environmental) benefits that they seek. The public, local/national authority is involved in CHP projects at least to some degree, normally in the procedures and documentation dictated by the framework. The relative involvement of the public or private sector depends broadly on two factors – the return on investment for project investors, and the degree of control and risk appetite of the public sector. The Return on Investment (ROI) is a financial metric that is dependent on both a project's Internal Rate of Return (IRR) and its Weighted Average Cost of Capital (WACC). The IRR is extremely site-specific and is developed initially by the project sponsor, which could be a private DHC company or private utility, or a public body such as a local authority or public utility. The IRR depends on the costs and incomes of the project. The WACC depends on the project's risk profile and its current and future sponsors, as well as on the debt-to-equity ratio of its financial structuring. Typically, while private sector investors will focus primarily on the financial IRR of a given project, the public sector, either as a local authority or a public utility, will also account for additional socio-economic and environmental costs and benefits that are external to standard project finance.

The public sector may wish to steer a DHC project towards a variety of local objectives, including cheaper local energy for public, private and/or residential customers (e.g., the alleviation of fuel poverty); local job creation; local wealth retention; low-carbon power generation; and/or local air pollution reduction. By quantifying these objectives through economic modelling, it is possible to realize **additional ROI** outside of the standard financial modelling. The degree of public sector control over a project can vary widely, ranging from full development, ownership and operation to a role focused mainly on project coordination, local planning and policy. The public sector also may wish to showcase the business case for DHC projects in the city by developing demonstration projects. Some cities and countries are more inclined to have energy services provided by public utilities, while others are more open to private sector participation. The degree to which private sector involvement in energy provision is the norm will influence the business model. The public sector is extremely important in project development because of:

- its ability to leverage finance for projects, such as through access to senior levels of grant funding and better access to capital,
- its ability to be a large, stable consumer and to provide off-take agreements,
- its longer-term planning focus, greater interest in meeting social and environmental objectives and ability to coordinate the multiple stakeholders involved in DHC.

There is a multitude of possible **ownership models** for DHC projects. The foundations on what models are possible and what are the required procedures are stated in national legislations. The ownership models for DHC projects can range from full public - state or municipal ownership, long term concession agreements with private operators for heat generation and distribution, “unbundled” networks with separate ownership of different network assets or a private owner/operator that bills and interacts directly with consumers. In its core, the ownership models can be categorized as municipality/state owned or a form of public-private partnership (PPP) and as a pure market operation (if allowed by the regulation).

In the **“wholly public” model** without any private participation, the city or municipality takes on most of the risk associated with the investment. In expansion or new cities, if a project has a low IRR, typically in the range of 2–6%, an internal department of the local authority can develop and operate the project to reduce administrative costs. Consolidated cities develop such projects via the public utility, and the low return is spread across other projects that have higher IRRs. Projects with a higher IRR in expansion or new cities are being developed by creating a “Special Purpose Vehicle” or subsidiary (such as a new public utility) to reduce the administrative burden on the local authority, with governance typically overseen by a board of directors that represents the local authority. Shifting to a subsidiary can provide additional benefits, including limiting the city’s financial liability in the event of project failure, increasing the flexibility and speed of decisions, and offering greater transparency and a more commercial operation. The local authority can outsource the technical design and construction (and sometimes operation) of the project to reduce risk related to the delivery cost and time frame.

A **Public private partnership** is a long-term contractual agreement on private provision of services that traditionally have been provided by the public sector. The term PPP covers several more specified models with partnerships between the public and private sector. These models are, for example:

- BLT Build Lease Transfer,
- BOO Build Own Operate,
- BOOT Build Own Operate Transfer,
- BOT Build Operate Transfer,
- BRT Build Rent Transfer,
- D&B Design and Build,
- DBFO Design Build Finance Operate,
- PFI Private Finance Initiative,
- FBOOT Finance Build Own Operate Transfer.

The above listed abbreviations consist of words and word parts like design, build, finance, own, operate, lease, rehabilitate, rent, and transfer. The common denominator of all these models is that the private sector partners have the responsibility for at least designing, building, and operating a project-facility.

In general PPP model is a very common practice in heat and cooling supply. E.g. in a FBOOT model – Finance, Build, Own, Operate, Transfer - a private operator designs, brings in the investment money, builds, owns and operates the energy supply system for a certain number of years, normally 20 to 25. Investment and operational costs are covered by subscription fees. The private operator undertakes the production of energy and its transfer to end users, tuning and servicing the grid and maintaining the necessary infrastructure.

PPP are models that reflect the increasing transfer of risk and responsibility from the public sector to private operators. In these models, political responsibility for the provision remains with the public authorities. Participation of the private sector should contribute to solving the challenges of the traditional model by providing long-term investment perspective, enabling access to additional investment sources, providing private sector experience, innovation. The involvement of the private sector through a PPP can create value for the public authority through:

- output-based contracting (compared to input based contracts when procuring deliverables under the traditional model),
- optimized risk allocation (which transfers project risks to the party most able to manage them),

- optimization over the project lifecycle (through the integration of responsibility for design, construction, and operation),
- improved incentives for quality service provision supported by performance-based payments (depending on quality of service delivered),
- access to additional financing sources.

PPPs are models that reflect the increasing transfer of responsibility for service provision, ranging from management contracts and lease contracts to concessions and private provision (privatization of existing assets and Build-Own-Operate for new assets), as well as models designed to address specific challenges in the DH supply chain, such as heat entrepreneurship (mobilizing the biomass supply chain) and ESCOs (addressing investment barriers at the end-user level). The key models for private sector participation in DHC are:

- **Management agreements**, where a company takes on the responsibility for managing the DHC system and conducting sales, as well as minor upgrades.
- **Leasing**, where a private party (lessee) takes on the operation, management, and implementation of facility upgrades under a contract with the public party (lessor).
- **Concession agreements**, where the concessionaire takes on the responsibility for investment in system upgrades under a long-term concession agreement.
- **Privatization**, where a private investor brings financing for DH and seeks recovery through heat sales, with the government providing framework conditions through tariff regulation, energy planning, standards, and norms.
- **Heat entrepreneurship**, a model developed in Finland since the early 1990s that facilitates the development of biomass-based heat generation and distribution through a partnership-based approach involving the wood fuel supply chain.
- **Energy service companies (ESCOs)**, which address investment barriers at the end-user level through provision of energy services to final energy users, including the supply and installation of energy efficient equipment and/or the refurbishment of buildings; they can arrange financing for the operation, with their remuneration being tied directly to the energy savings achieved (Energy performance contracting). The EU-directive on energy and end-use efficiency provides the following definition of ESCO: *"a natural or legal person that delivers energy services and/or other energy efficiency improvement measures in a user's facility or premises, and accepts some degree of financial risk in so doing. The payment for the services delivered is based (either wholly or in part) on the achievement of energy efficiency improvements and on the meeting of the other agreed performance criteria;".*[25]

Table 4. Private sector participation models overview.

	Operation and management	Payment for services	Investment	Ownership
Traditional public provision	Public	Public	Public	Public
Management agreements	Private	Public	Public	Public
Leasing	Private	Private	Public	Public
Concession agreement	Private	Private	Private	Public
Privatization	Private	Private	Private	Private
Heat entrepreneurship	Private	Public/ Private	Public/ Private	Public/ Private
ESCO's	Private	Private	Private	Public/ Private

[25] DIRECTIVE 2006/32/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL. 2006/32/EC, Art. 3.1.)

5.1.1 Traditional public provision of DHC

Traditional public supply of heat in a DH project is when the service is provided by the government or municipality or by a public authority or a publicly owned company. National frameworks define exact procedures and options for public provision of DHC. The legislation can vary country to country.

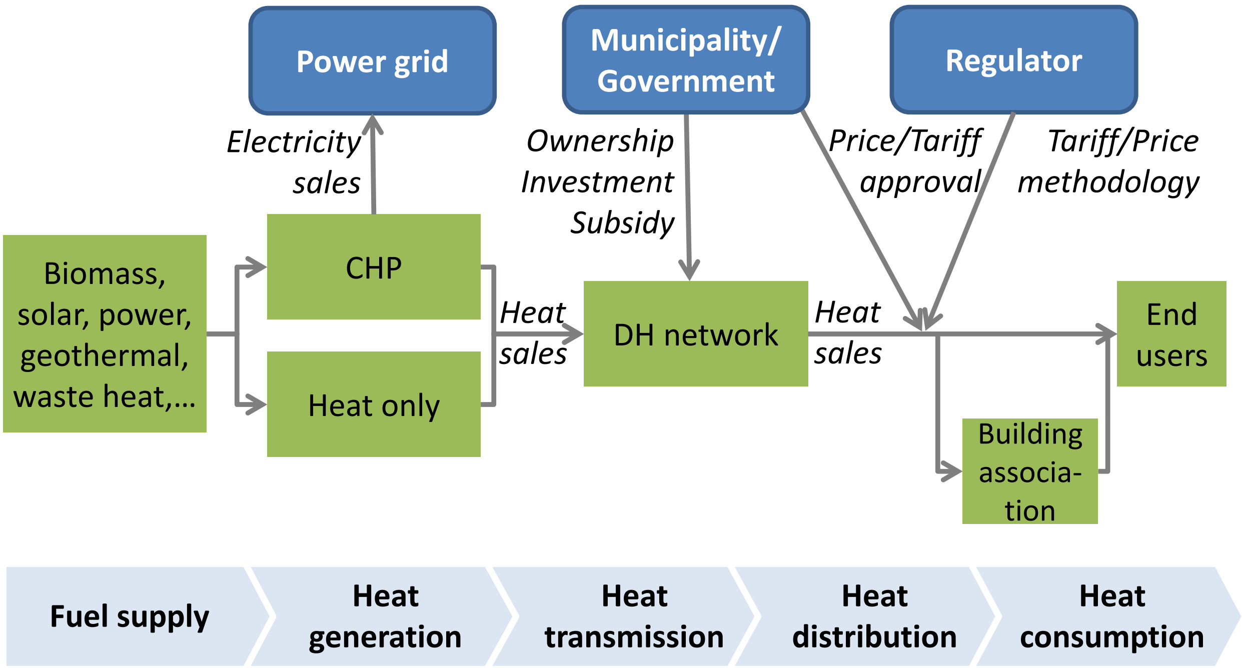


Figure 4 DHC value chain, from fuel supply, heat generation, and transmission, to the distribution of the heat to end-users (including possible building association as owners of residential buildings supplied).

Under the traditional model, the government (national or regional/local) owns the heat generation plant and also owns the DH network, regulates the sector, provides investment support, and determines tariffs.

Many examples from European countries suggest that any drive to deploy low/no carbon heat delivery system must be led by the public sector. However, the traditional model is frequently characterized by challenges related to inadequate maintenance, insufficient funds for infrastructure development, poor planning and project selection, as well as inefficient or ineffective delivery. These facts represent key reasons for alternative ownership and financing models involving the private sector through public-private partnership (PPP) or private sector participation. In such models private sector maintains control of the relevant planning decisions and new development directions and own or are in close relationship to owners of buildings which can represent the core of the DH consumer net. And the private sector participation can bring in many more additional benefits as it will be explained in the following sections.

5.1.2 Management Agreement

A management agreement involves outsourcing of the public service management, while the ownership and investment decisions are retained in the public sector. These agreements are usually short term (two to five years) and do not involve transfer of employees to the operator. The (private) operator is paid a fixed fee to cover its staff and expenses, which can be complemented by a performance-based fee linked to the quality of the service provision, with liquidated damages for failure to achieve performance parameters.

The management agreement obliges the operator to collect bills on behalf of the utility and may accept some collection risk in terms of performance standards. Management agreement can include obligation on the private operator to operate and maintain the operation, and they may include the cost of routine replacement of components of equipment.

The benefits that can be realized from a management agreement compared to the traditional model include addressing issues of poor management in an existing public company and enabling a separation of the operation and regulation of district heating. However, it should be noted that management agreements have only limited potential for improvements in efficiency and performance, and they typically do not bring in largescale financing.

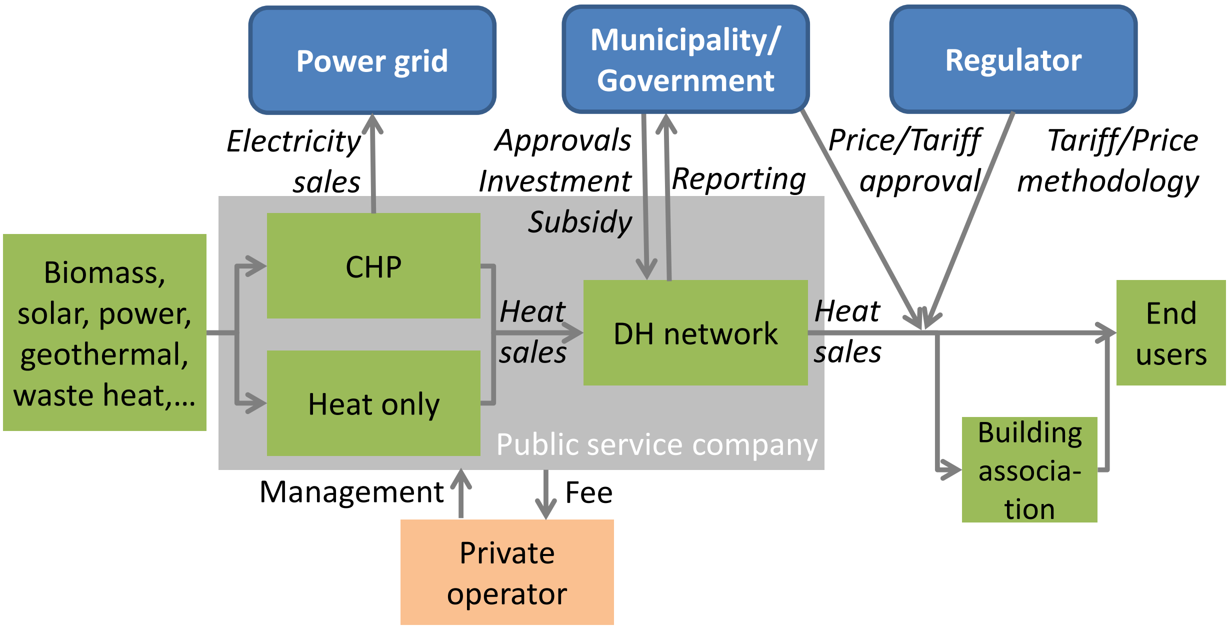


Figure 5. Management Agreement Model.

The figure above illustrates management agreement for provision of DH. In this example the management agreement covers heat generation as well as transmission and distribution, which is assumed to be combined in one public service company. The management agreement could also be limited to a part of the value chain, e.g. if generation and transmission/ distribution would be in several public entities.

5.1.3 Lease agreement

In a lease model a private party (lessee) takes-on the operation and management of a DHC system, as well as the implementation of facility upgrades, under a contract with the public party (lessor). The public party (lessor) receives rent payments from the lessee, which are reinvested into operation upgrades (obligation by the lease contract). Lease agreements are of medium-length – usually 8 to 15 years and usually involve employees being seconded or transferred to the operator.

The lessee (private party) recovers the lease costs via the operation; the revenue collection risk is passed to the lessee. Therefore, the lessee requires assurances as to the tariff levels and increases over the term of the lease, as well as a compensation/review mechanism if tariff levels do not meet projections. The cost of maintenance and some replacement is passed to the lessee, and the lessee assumes some degree of asset risk in terms of the performance of the assets. Furthermore, the lessee may be put in charge of overseeing the capital investment program/ specific capital works. The lessee will maintain an asset register and operation and maintenance manuals/records, etc., and the contract typically will include minimum maintenance or replacement provisions toward the end of contract to ensure that the facilities are handed back to the lessor in an operational state.

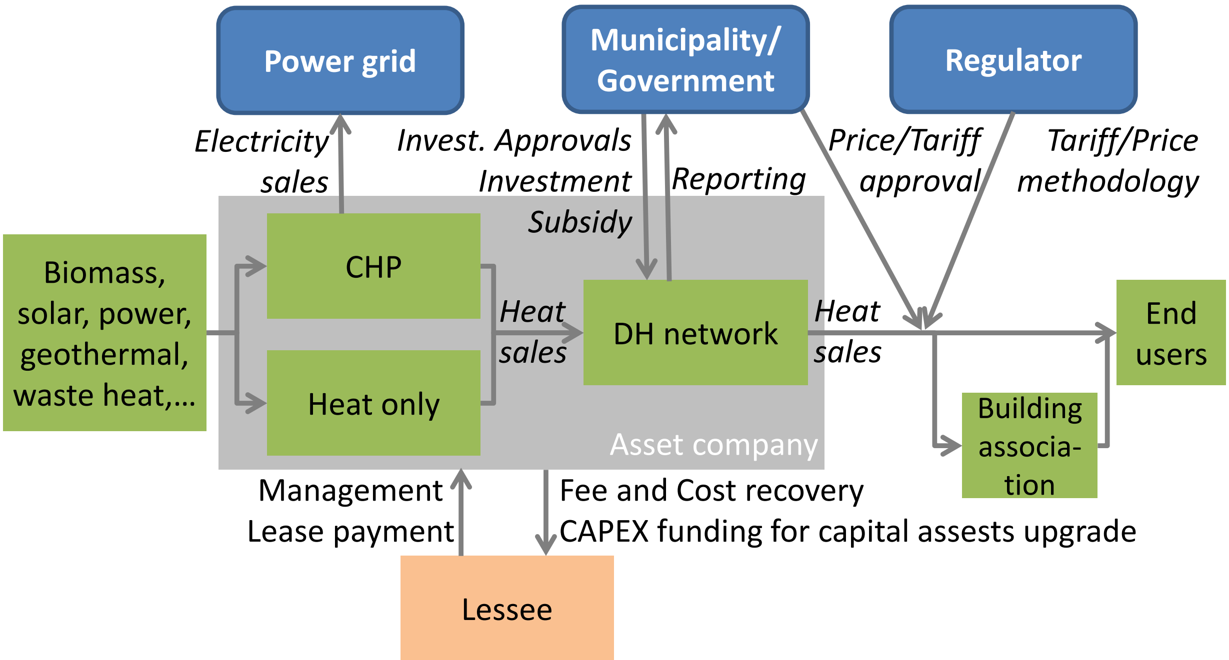


Figure 6. Lease agreement model for DHC.

In a lease model operation and management, revenue collection and investment are privately managed but ownership remains public. In addition to the benefits realized under a management agreement, a lease agreement provides stronger incentives for operational efficiency and improved asset management. But a lease agreement also limits the authority's right to intervene and involves a risk of degraded asset quality at hand-back if not adequately regulated in the lease agreement. Furthermore, lease agreements typically do not mobilize additional capital. In the figure above the example shown covers generation as well as transmission and distribution, but the lease agreement could also be for a more limited part of the value chain.

5.1.4 Concession Agreement

Under a concession agreement, the public authority grants the concessionaire (private party) the right to renovate, finance, and operate an existing infrastructure asset, or (in the case of a Build-Own-Operate-Transfer) to design, build, finance, and operate a new infrastructure asset. The assets very often remain owned by the public sector, but concession agreements are long-term in nature (typically 25–30 years or the life time of the facility) in order for the concessionaire to recover the investments, after which responsibility for the operation reverts to the public authority.

The concessionaire returns its investment, operating, financing costs, and profit by selling its services directly to the end-user of the services. The concessionaire usually pays a concession fee to the awarding authority. The concessionaire usually assumes risk of demand for use of the asset, risks of design, finance, construction and operation. The public authority, however, may share the demand risk by agreeing to a minimum level of usage.

User charges may either be prescribed in the contract or set by the concessionaire under supervision of a sector regulator. The benefits of concession agreements include the benefits of management agreements and lease agreements; in addition to this, a concession agreement provides stronger incentives for operational efficiency and for optimizing life-cycle costs, and, importantly, well-structured concession agreements may mobilize additional financial resources.

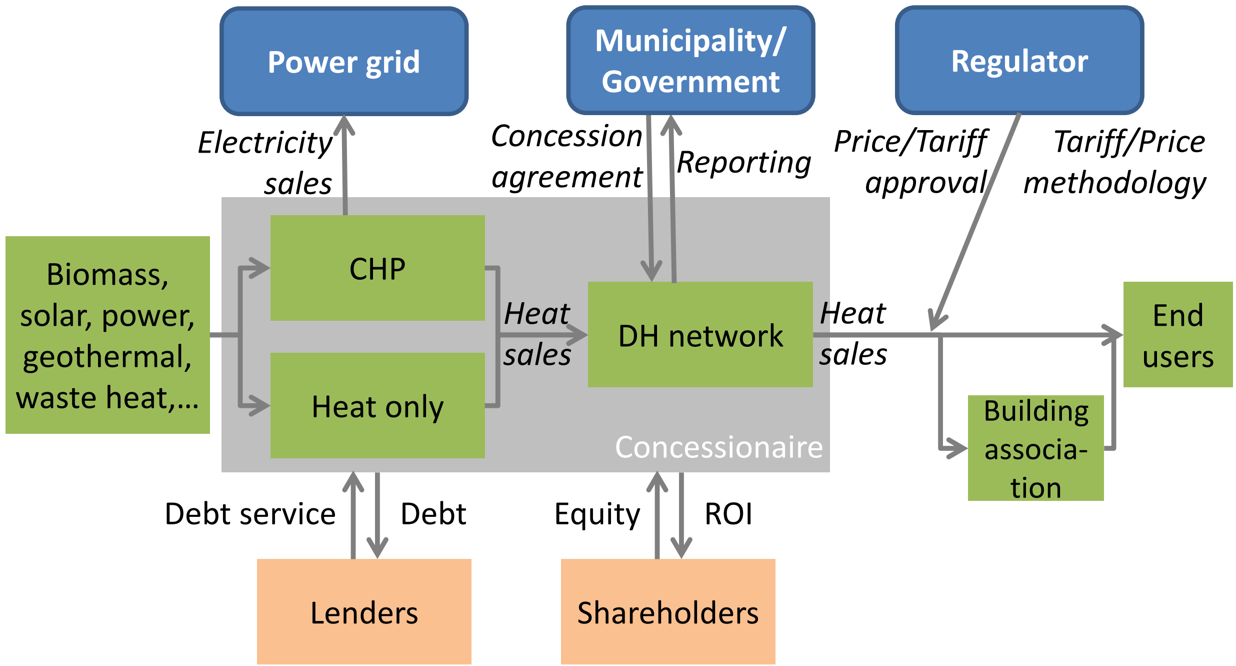


Figure 7. Concession model for DHC.

The figure above shows an illustration of a concession agreement for provision of DHC. The scheme covers both, generation as well as transmission and distribution, but the concession agreement could equally be for a more limited part of the value chain.

Concession agreements require relatively advanced framework conditions: the responsible authority has to be willing to delegate operation and maintenance, design, and investment decisions; the tariff determination has to be independent or backed by a compensation mechanism for inadequate adjustments; the output-based requirements and allocation of project risks have to be defined prior to contracting; and obligations related to present workers and non-commercial service have to be addressed upfront.

5.1.5 Privatization

Privatization may involve full divestiture of an existing utility or private provision of new assets through Build-Operate-Transfer. Full divestiture of an existing utility usually will be accompanied by limitations on the private operator, which will be required to hold a license to provide the service, and such license is subject to termination.

Another form of privatization is private provision of a new asset through a Build-Operate-Transfer contract. This typically is used for entirely new or Greenfield operations. For Build-Operate-Transfer projects, the operator generally obtains its revenues through a performance-based availability payment charged to the utility/government rather than through tariffs charged to consumers.

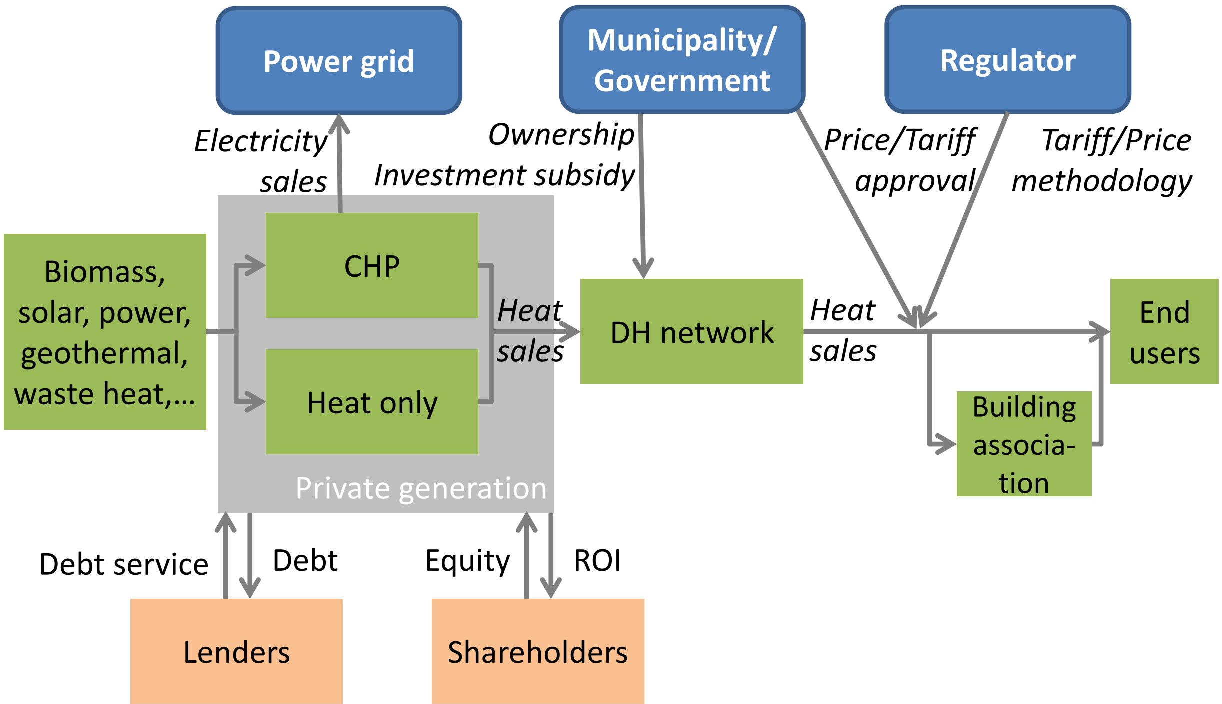


Figure 8. Privatization model of DHC.

The figure above provides an illustration of privatization or private provision of heat generation assets. The revenue basis is a combination of electricity sales to the power grid (under a power purchase agreement) and heat sales to the public DH transmission company (under a heat purchase agreement).

5.1.6 Heat Entrepreneurship

Heat entrepreneurship models differ from traditional energy models, because in most cases it is the customer who invests and, thus, the ownership relations are separate between the customer and the entrepreneur. The heat entrepreneurship model has been developed in Finland since the early 1990s to facilitate the development of biomass-based heating plants and DH networks through a partnership approach. A key feature in this development in Finland is the involvement of the biomass/wood fuel supply chain (for example, through equity participation in the generation capacity) to reduce supply chain risks, as well as a carefully crafted balance of ownership and responsibilities among stakeholders.

A heat entrepreneur or enterprise can be a single entrepreneur, entrepreneur consortium, company or cooperative providing heating for a community. Heat entrepreneurship may be **“investment by customer,”** where the entrepreneur oversees the practical operation and maintenance, while the municipality bears the investment risk; here, the involvement of the heat entrepreneur has parallels to a management contract. Heat entrepreneurship can also be a community-owned not-for-profit or cooperative model where a municipality can establish a DHC system as a mutual, community-owned not-for-profit or cooperative. In Denmark, all utilities are required to be not-for-profit mutual’s (break-even principle), cooperatives, or municipally owned. In the not-for-profit or cooperative model, the local authority initially takes on a large share of the risk. Once the mutual is well established, risks to the local authority decrease. Some risks can be passed through to contractors for design and construction.

Alternatively, heat entrepreneurship may be **“investment by entrepreneur,”** where the entrepreneur (or a third-party investor) bears the investment risk, and the involvement of the entrepreneur resembles a concession agreement.

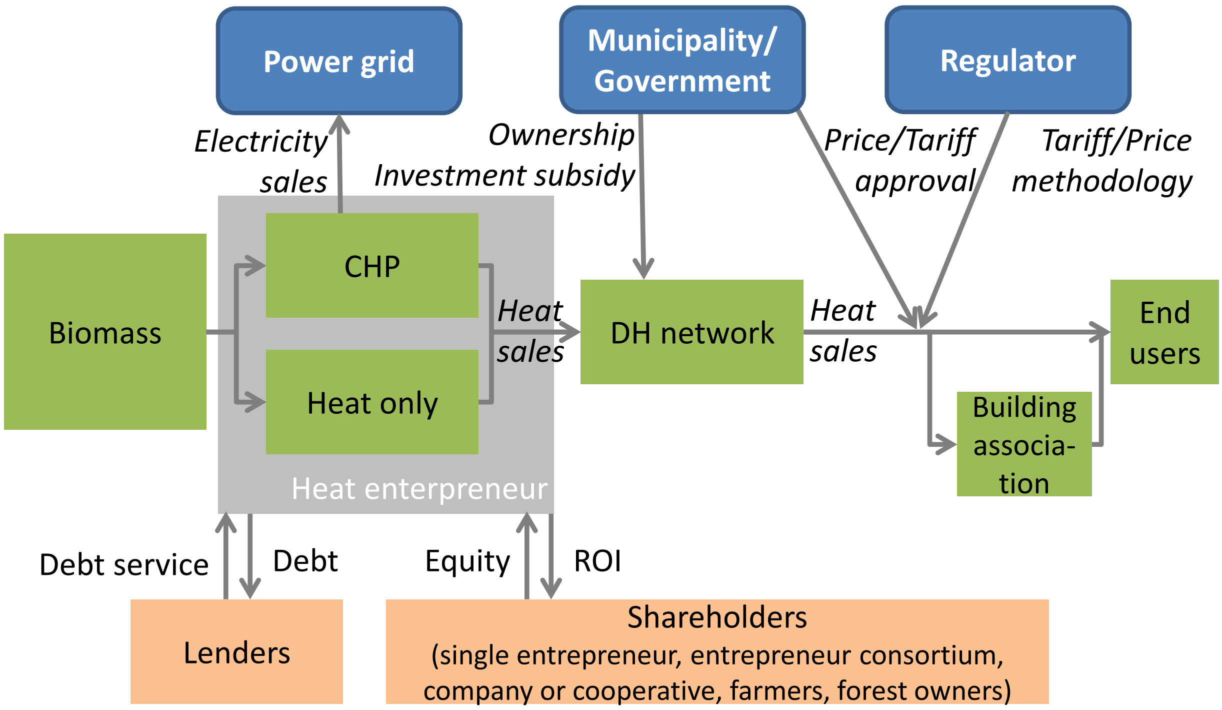


Figure 9. Heat Entrepreneurship Model

The Figure above provides an illustration of heat entrepreneurship. In the scheme, the heat entrepreneurship does not encompass heat transmission and distribution, but that could also be included. The model's key difference from the other PPP models is the explicit focus on involving the biomass supply chain. This makes the model specifically suitable for the establishment and operation of new generation capacity based on biomass and for the management of the related supply chain, and the solution may be implemented independently of the ownership and management model selected for the rest of the heating system.

As has been shown in the example in Finland municipalities play a key role in the establishment of enterprises that have taken the responsibility for heating public buildings, such as hospitals, schools, offices and libraries, as well as private houses and industrial estates. Privatization of heating in Finland provided mutual benefits: for heat entrepreneurs (e.g. forest owners, local farmers and contractors) entrepreneurship provides extra income, benefits of improved forest management, use for under-utilized harvesting equipment and increased employment. While for the municipality, a well-established heat entrepreneurship provides increased security of heat supply, savings in operational and investment costs of energy production when fuel oil is replaced with cheaper wood fuels, increased use of local work-force and creation of new business opportunities, support for existing employment (e.g. contractors), environmental benefits and local direct, indirect and induced economic impacts of local spending[26].

The more parts of the value chain the entrepreneur/cooperation is capable of handling, the higher the better for the economy of the business model. If an entrepreneur produces the raw material from their own forest (e.g. forest cooperatives or trusts), takes care of transportation, storage, chipping and heat production in his own heat plant, the cover from the sold energy is the highest. However, this requires efficiency of operations in each stage of the production process.

[26] L. Okkonen, N. Suhonen (2010), Business models of heat entrepreneurship in Finland

Text box 1. Example for the Heat Entrepreneurship ownership model. (Source: Okkonen et al., 2010).

Eno Energy Cooperative was established in 1999 after three years of meetings between entrepreneurs, the local forestry centre and the municipality. An important back-up has been the municipal strategy with a political statement supporting local wood energy production.

The main operations of the cooperative include the acquisition of the raw material, communition, and service and maintenance works of three district heating plants. In addition, a local entrepreneur is contracted to take care of the communition. In the very early stage, the cooperative used the Yl¨akyl¨a heating plant that was invested in and owned by the municipality of Eno.

After some years of gaining experience, the cooperative invested in Uimaharju (2002) and Alakyl¨a (2004) heating plants and district heating networks. The annual heat production, about 11 GWh, results in sufficient cash-flows to make it a profitable business. The annual turnover of the cooperative is approximately 650.000€. The cooperative has about 50 members, mostly forest owners. In addition, there are people involved in forest machine contracting, sawmilling, some with engineering and also administration and management skills. This is consistent with the earning logic of a complementary partnership. The investment by entrepreneurs in the two heating plants and networks, have saved municipal finances for other purposes. On the other hand, as a result the decision-making power has shifted more to the cooperative. However, any uncertainties can be decreased by a detailed contract and well-established heat pricing mechanisms.

5.1.7 ESCO

An energy services company (ESCO) provides energy services to final energy users (such as households), including the supply and installation of energy-efficient equipment and/or building refurbishment. In a “shared savings” model, the ESCO makes investments, whereas in a “performance guarantee” model, the ESCO provides a savings guarantee and the host company or housing association makes investments. The ESCO guarantees energy savings and/or provision of the same level of energy service at lower cost, and the return of the ESCO’s investments is tied directly to the energy savings achieved. Therefore, the ESCO accepts some degree of risk for the achievement of improved energy efficiency.

ESCOs not only focus on energy saving concepts to improve energy efficiency, but also to produce and utilize renewable energy. The payment for the services delivered is based on the achieved energy efficiency improvements, reduced energy costs or other agreed performance criteria. Energy performance contracting (EPC) is a contract between the beneficiary and the provider, typically ESCO, of an energy operation, where the investment is paid according to contractually agreed level of energy efficiency improvement. In heat production, the ESCO invests in heat production equipment while the customer pays the same price for the heat as before the investment. The heat produced with the new system (e.g. wood fuel) is cheaper than the older (fossil fuel) system. After the ESCO has recouped its investment, the customers get ownership of the equipment and also lower heating costs.

The ESCO’s operations are often difficult to apply successfully on a small scale due to long payback periods of investments. If an ESCO makes several investments, significant financial resources are needed. On the other hand, the ESCO will have ready-made concepts and skills to run the operations. A stable price level at the payback time also reduces the ESCO’s financial risk. From the customer’s point of view, the strengths of this model are small investment risk, steady heat price for an agreed period and ownership of the equipment. In some countries, the ESCO market has been facilitated by third-party insurance of the energy savings, with such risk mitigation instruments typically being supported by development banks.

There is a useful implication from this model, which can be used also in other DHC business/ownership models. The key aspect in consumer willingness to connect to the DHC grid is the end cost for the consumer. The end cost consists of energy price for which consumer expects to be same or lower than his existing heating price and the costs of attachment to the DHC grid. The connection cost to the district heating grid can be subsidised for the consumer in the ESCO principle. The consumer does not pay for the connection; instead the connection cost is covered by the energy price. The figure below provides an illustration of an ESCO for end-user energy efficiency in DH.

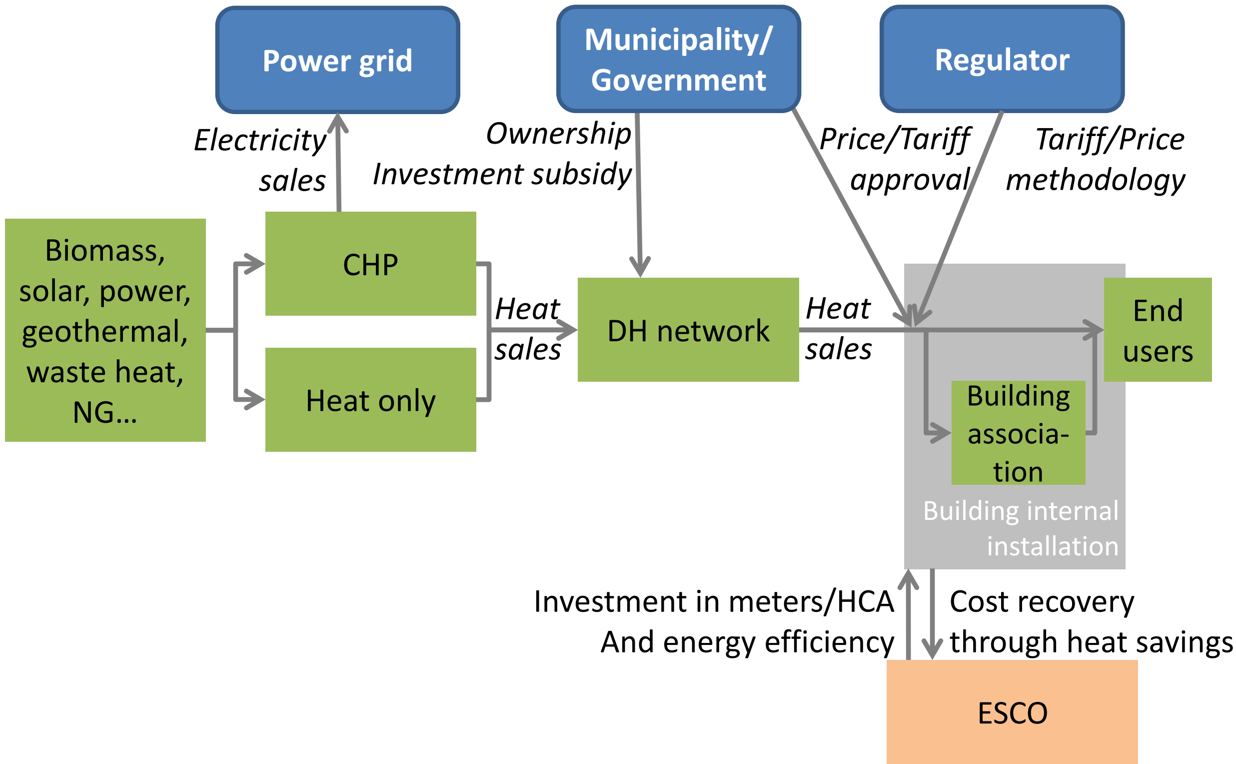


Figure 10. ESCO Model for End-user Energy Efficiency in DH.

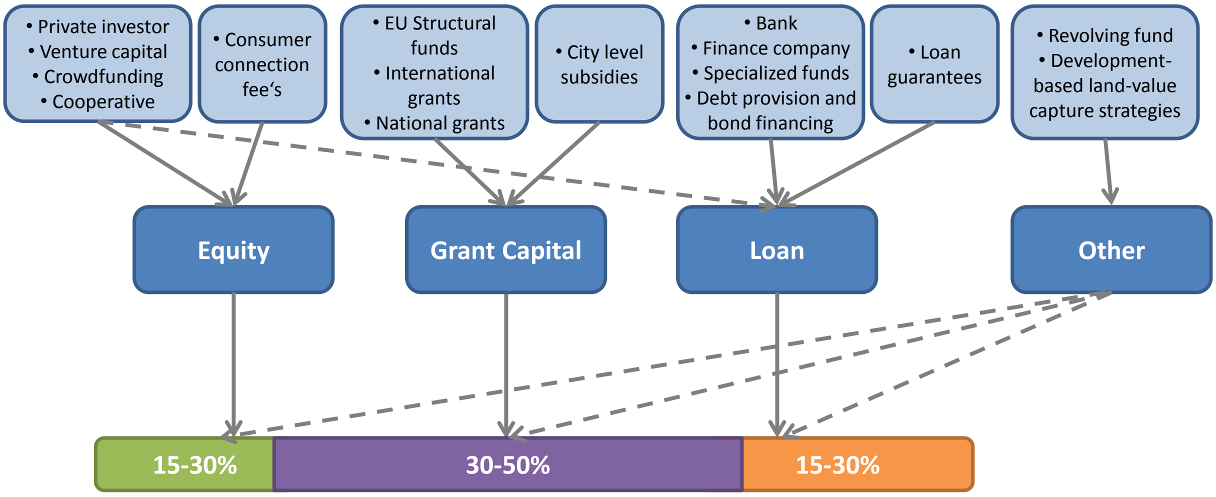
5.2 Financing sources and schemes for DHC projects

The upfront capital costs involved in DHC projects are significant. District heating networks should eventually pay for themselves, but it can take 8-10 years for the initial outlay of the design and build to be recovered and for any profits to be generated. This means that district heating projects need investors who are looking for a relatively secure long-term revenue stream rather than a quick return on their capital. The combined heat and power projects generate more revenues which can be used to improve the consumer price or to improve the ROI, thus making the project more lucrative for potential investors. There are often fundamentally different motivations for DHC projects initiated, developed and financed by public or the private sector. The public sector will pursue lower heat price and better socio environmental impacts and the private sector will primarily pursue better economy.

A DHC project with a low IRR will compete for financing with other municipal, regional or national projects. To the extent that a DHC system contributes to a city's strategic objectives, as reducing environmental burdens, improving resilience or energy security, or providing affordable heat supply, projects often leverage the city's cash reserves and/or public debt raised based on the balance sheet of the local authority. The lower interest rate of public debt is why many proponents of DHC projects argue that cities can (and should) be investing in this way, and why several DHC models are locally led. For example, the £3.5 million connection between London's publicly owned Westminster and Pimlico heat networks (Arup, 2014), which aimed to improve efficiency through pooled networks, was far cheaper through public backing (an IRR of 16.6%) than private sector financing (an IRR of 9.24%), even though the anticipated cash flow revenues are the same in both cases. The difference is due to lower risks and financing costs because of public backing.

If a local authority has a potential DHC project with a high return on investment (usually more than 12%, although it can be lower for lower-risk projects), and the local authority has a low risk tolerance and a relatively low desire for control, it may be able to attract interest from private sector companies. This does not mean that the local authority is removed from the project; many successful privately owned district energy systems still have arms-length local authority involvement. For example, the local authority may have been the original project proponent and/or it could still attract financing and grants for the project. The local authority may help with any connections deemed socially optimal that are too high risk for the private sector. It could also develop initiatives that encourage social or environmental objectives, such as mechanisms that support low-carbon generation.

Figure 11. Visualisation of the financing structure. Proportions are indicative.



The framework of various types of financing sources employed in an investment represents the financing structure. Commonly, it comprises of stockholders' (shareholders') investments (equity capital), long-term loans (loan capital), short-term loans (such as overdraft or bridging loan in case of approved investment subsidies), and short-term liabilities (such as trade credit) as reflected on the right-hand side of the firm's balance sheet. In DHC projects the financing structure usually includes also capital from investment support grants. Frequently these additional investment funds are making DHC projects based on RES competitive. In the following paragraphs various types of financing relevant for DHC projects are described.

The usual financing structure for a DHC project is developed around the possible grants/subsidies obtainable for the desired project. The grant regulative defines the proportion of investment covered by that source. The loan regulation usually defines what amount of equity is expected by the loan-giver to be provided in the financing scheme. Based on that information the required equity is defined.

5.2.1 Equity

Equity capital represents the personal investment of the owner(s) in the project. It is often called risk capital because investors (owners) assume the risk of losing their money if the business fails. In contrast to the loan capital it does not have to be repaid with interest, but is instead reflected in the ownership structure of the planned project. Equity capital is available from a wide variety of sources which include the entrepreneur's own resources, private investors (from the family physician to groups of local business owners to wealthy entrepreneurs known as "angels"), employees, customers and suppliers, former employers, venture capital firms, investment banking firms, insurance companies, large corporations, and government-backed Small Business Investment Corporations (SBICs).

All investment schemes incorporate equity capital which represents the “cash” in the investment structure. It can be provided internally by those developing the project –

municipality/company/cooperative/individual. However, if this is not the case equity capital can also come from external sources. The most common sources of equity capital are:

- **Private equity** is the provision of equity capital by project initiators or financial investors over the medium or long term. The private equity can be provided by external investors in form of ownership or in the form of a loan. Usually private equity is an expensive part of the financing structure – private equity loans can hold over 10% interest rates. Therefore this type of capital should be minimised in a financing structure. It is also advisable to use specialised private equity investors for the sector in which the investment will be executed. Specialised investors possess good knowledge and a wealth of experience and are able to support the investment in its life cycle.
- **Venture capital** usually provided by investors to start-up companies and small businesses that are believed to have long-term growth potential. Risk is typically high for investors, but the downside for the start-up is that these venture capitalists usually get a say in company decisions. Venture capital generally comes from well-off investors, investment banks and any other financial institutions that pool similar partnerships or investments. Capital infusions are just one benefit as this type of equity can provide also a technical and managerial experience. For small businesses, or for up-and-coming businesses in emerging industries, venture capital is generally provided by high net worth individuals (HNWIs) – also known as ‘angel investors’ – and venture capital firms. Most venture capitalists take an active role in managing the companies in which they invest. Many venture capitalists focus their investments in specific industries with which they are familiar.
- **Crowdfunding / cooperative**. Cooperatives are business enterprises, not charitable organizations, so they are not the same as non-profits; yet they do not exist to maximize profits, so they are not the same as investor-owned firms. Cooperatives are enterprises that are democratically owned and controlled by the people who benefit from them and are operated collaboratively for the purpose of providing services to these beneficiaries or members. In DHC cooperatives provide own funds for the investment structure. These funds can represent equity and can be translated into investment ownership. However, cooperative funds, the same as venture capital funds, can also represent a loan given to the project operator and shall be returned by the DHC company, in which case these funds are translated into loan capital.
- Usually minor sources of equity in the investment structure can also be funds provided by the **connection fees**. Return on investment is entirely dependent on the customer base of the network, so it is imperative that a scheme targets customers who can pay. This makes public sector buildings, communal facilities and large manufacturers ideal customers because they should be able to pay their bills. Individual households, on the other hand, represent greater credit risk. In similar sense the connection fees for large industrial and public consumers can be negotiated, contracted and collected in the investment phase and can represent a minor part of the investment equity capital.

5.2.2 Loan capital

Debt or loan capital is the capital that a business raises by taking out a loan and which is normally repaid at some future date. Debt capital differs from equity capital because subscribers to debt capital do not become part owners of the business, but are merely creditors, and the suppliers of debt capital usually receive a contractually fixed annual percentage return on their loan. This part of the investment funds must be repaid within a specified period with an established interest rate, irrespective of the company's financial position. Loan types vary by length of time, by how interest rates are calculated, by when payments are due and by a number of other variables. In its simplest form, interest is the cost of borrowing money, and it is normally expressed in terms of a percentage of the overall loan. Not only will the investor have to pay back the original amount of money borrowed (the principal), but also the cost of borrowing that money (the interest, plus any setting up fees etc.). How much interest has to be paid on any given loan is subject to a number of different factors, depending on which lending institution you borrow the money from and the terms of the loan. Fixed interest rate is simply as the name suggests: a fixed percentage on the loan that must be paid back during the life of the loan. Fixed interest rate loans make it very easy to calculate the exact amount of money the borrower will have to pay back each month as the amount never changes. Typically, fixed interest rate loans attract a slightly higher interest rate than a more common variable interest rate loan - but that higher interest rate is offset by the certainty of the cost of the loan. Variable interest rate loans allow the lender to set the interest rate to whatever market conditions demand at any given time during the life of the loan. The attraction of variable interest rate loans is that the investor can benefit from any future drop in market interest rates when his monthly repayments are reduced to reflect the lower interest rate. However, the opposite also holds true. If the market decides it is time for interest rates to rise, so too will the repayments. The investor must make sure he fully understands the consequences of a variable interest rate loan if he is considering taking one out. If interest rates rise dramatically the project could get in serious financial difficulties and business can default simply due to poor financial management rather than because of operational difficulties.

Loan capital can be further distinguished by the duration of the loan. In this sense we can talk about the short term and the long term loans. Short term loans are essentially loans with a validity period of 3 years or less. This means the loan has to be repaid within a time period ranging from 0 to 3 years. Long term loans, however, have a statutory payback period of more than 3 years. The repayment period for long term loans can extend from 3 years to 30 years or even more. It should not be assumed that the difference between the two is purely in the naming. The actual distinction between short term and long term loans is quite wide and requires comprehensive understanding, but generally speaking long term financing is for assets and projects and short term financing is typically intended for financing continuing operations. A special type of short term business loan is also a bridging loan. As DHC projects often include in their financing structure investment grants and subsidies, the bridging loans have quite an important role in this type of project financing. Investment grants are normally passed on to the investor only after he can prove the payment of the assets for which the subsidies were granted. This means that the investor has to secure some temporary financing sources until he receives the approved grants. In this situation the bridging loans serve to bridge the gap between the cash outflow for asset acquisition and the cash inflow from the available grants.

And finally there are also certain loans that are a combination of debt financing and grants. A loan with subsidized interest rate is an example of this kind of hybrid financial mechanism. It does not defer from the normal loan type, the only difference is that the interest rate is lower than the normal market interest rate in the specific time moment. There are usually specific state owned institutions that provide loans with subsidized interest rate in order to facilitate investments into strategic ventures, which DHC projects certainly are as they form part of the development strategies on the European level.

Certain financing schemes also allow an option of the moratorium or initial deferment. A moratorium period is the duration in the loan term when the borrower does not have to pay any money i.e. no repayment. It is the waiting time before the repayment begins. This tenure usually starts with the date of disbursement of loan. In a common man’s language it is the holiday period on the timeline of your repayments and it ensures that the investor’s repayments start only after the business operations have been set up, the business cycle starts to generate cash flows from the revenue creating operations and some breathing space being obtained. As the investments in DHC projects are financially intensive and time consuming, a deferred payment or moratorium is usually a very welcoming option for project developers.

Loan capital may be obtained from a bank, finance company or other financial institution as long-term loans, or from specialised funds for projects utilising RES, also from debt-equity investors in the form of debentures or preferred stock (preference shares), and is usually secured by a fixed and/or floating charge on the company's assets. Also called borrowed capital, loan capital therefore can be obtained from a variety of institutions which provide loan capital under different conditions. Typical financial institutions supporting RES project through the supply of debt capital are national banks, European Bank for Reconstruction and Development (EBRD), World Bank (WB), European Investment Bank (EIB) specialised funds for RES, Swedish International Development Cooperation Agency (SIDA), Kreditanstalt für Wiederaufbau (KfW) et cetera.

Obtaining a loan normally requires providing a loan guarantee or a type of loan insurance. A loan guarantee is a promise by one party (the guarantor) to assume the debt obligation of a borrower if that borrower defaults. A guarantee can be limited or unlimited, making the guarantor liable for only a portion or all of the debt. National subsidy schemes in some countries also provide guarantee schemes for DHC projects utilising RES. In asset based debt the guarantee is assured by an asset. This means, if the loan is not repaid, the asset is taken. In this sense, a mortgage is an example of an asset based loan. Typically, these loans are tied to inventory, accounts receivable, machinery and equipment which are the subject of the investment.

5.2.2.1 Debt provision and bond financing

Cities can provide low-cost loans to projects by passing on their ability to raise low-cost recourse capital. Similarly, cities can issue general obligation bonds to provide debt to a project. Revenue bonds can also be issued to effectively provide this debt at a higher interest rate. Using non-recourse loans and revenue bonds in project financing will have a high due-diligence cost and is best suited to mature markets or in combination with connection guarantees. In St. Paul, Minnesota USA, long-term revenue bonds were issued to develop both the heating and cooling networks, and the city was able to avoid having to guarantee debt repayments. This was made possible by the signing of long-term contracts with initial customers.

5.2.2.2 Loan guarantees and underwriting

Loan guarantees from cities allow access to low-interest debt for projects, which can greatly reduce the total project cost. Creditors may require some form of loan guarantee from municipalities, obliging the city to repay the loan if the project defaults. In the U.K., the Aberdeen City Council underwrites (via a loan guarantee) the not-for-profit district heating company, allowing it to obtain commercial debt financing at attractive rates. In Denmark, district energy companies similarly may request that their municipality act as guarantor for the needed loans. This “kommunegaranti” reduces lenders’ risk and thus lowers interest rates. KommuneKredit, a credit union for Danish cities, lends out more than DKK1 billion (US$176 million) annually to district energy companies that hold the kommune-garanti. Since the early 1990s, there has been no instance of a municipal government being called upon to cover the losses of such loans (Chittum and Østergaard, 2014).

5.2.3 Grants

The majority of financing structures for DHC projects include funds from grants, either in the form of capital grants or in the form of subsidized interest rate loans. Grant funding of district energy systems tends to come from higher levels of government rather than the city or town itself. This financing opportunity reflects the national and international importance of DHC and use of RES and represents a key financing element for DHC projects. Especially in RES based DHC in order to reduce the investment cost and thus enabling competitive heating and cooling consumer price. It also means that the municipalities have the opportunity to better leverage its project money if it is engaged more fully in the business model (such as with equity or debt provision). It is important to underline that the local authority can help individual projects gain funding from national or international grants, e.g. Rotterdam was able to secure a 27 million € grant from the Dutch government to reflect the equivalent avoided social costs of CO_2 and NOX emissions. The project CELSIUS, a grant programme provided by the EU, is financing innovative demonstration projects in London, Rotterdam, Gothenburg, Genoa and Cologne. Brest has attracted a 9 million € grant from ADEME (Agence de l'Environnement et de la Maîtrise de l'Énergie) that will help double the heat network in the city and surrounding area and install seawater heat pumps, biomass boilers and heat storage. This national grant is financed from the country's "Heat Fund" to projects that reduce CO_2 emissions and imports of fossil fuels.

Cities/municipalities may also provide capital grants or annual payments to specific projects to enable their initial development or to help direct them to social or environmental objectives. The City of London has provided development grants for early-stage feasibility assessments and investment-grade audits. The first phase of the Bunhill Heat and Power project in the city's Islington borough, which aims to provide cheap heat to social housing, benefited from £4.2 million (US$6.7 million) in grants from the London Development Agency and the Homes and Community Agency.

Given the type of investor there is a variety of available capital or loan grants for DHC projects based on RES:

- EU Structural and Cohesion funds
    - European Regional Development Fund http://ec.europa.eu/regional_policy/en/funding/erdf/
    - Cohesion Fund http://ec.europa.eu/regional_policy/en/funding/cohesion-fund/ ,
    - European Agricultural Fund for Rural Development http://ec.europa.eu/agriculture/rurdev/index_en.htm
- Grants for innovative, demonstration, pilot, lighthouse projects
    - HORIZON2020 https://ec.europa.eu/programmes/horizon2020/en/
    - NER 300 https://ec.europa.eu/clima/policies/lowcarbon/ner300_en
    - The LIFE Programme and its Private Finance for Energy Efficiency instruments (PF4EE) http://ec.europa.eu/environment/life/funding/financial_instruments/pf4ee.htm
    - ManagEnergy http://www.managenergy.net/
    - EEA Grants and Norway Grants http://eeagrants.org/
    - EIB European Investment Bank http://www.eib.org/
    - European Energy Programme for Recovery http://ec.europa.eu/energy/eepr/projects/
    - Connecting Europe Facility https://ec.europa.eu/inea/en/connecting-europe-facility/cef-energy
    - Breakthrough energy private fond http://www.b-t.energy/
- National specialised subsidy schemes for DH projects in form of capital or loan grants (e.g. in Slovenia there is a loan grant scheme Eko sklad and a capital grant scheme JR DO OVE 2016 for DHC projects based on RES realised in Slovenia). For access to national support schemes national energy agency and the competent ministry should be contacted.

Many innovative projects were able to receive financing sources from funds which are initially intended for a non-energy related projects. Innovative project developers are able to incorporate DHC investments also in projects aimed at specific sectors as tourism, agriculture, forestry, regional development. In Murska Sobota, Slovenia an innovative project Turistični center Fazanerija received financing from a regional development fund intended for tourism where the project integrated geothermal energy (2 new geothermal wells and refurbished DH grid) with the geological and geothermal tourism activities (visitor center, geothermal and geological heritage and history).

City-level subsidies

Although many countries provide national subsidies for low-carbon or energy-efficient heating or cooling, subsidies developed at a city level are less prominent. In Botosani, Romania municipal heat networks historically were heavily subsidized by municipalities to account for inefficiencies in the network and to protect the population from high heat prices (Sharabaroff, 2014). Some cities exploring modern district energy systems have been advancing mechanisms – such as feed-in tariffs, net metering and heat incentives – that internalize the public benefits of these systems, in association with a public utility. Seoul has a city-level feed-in tariff for CHP, and Tokyo even initiated a cogeneration subsidy to encourage increased electricity generation in response to the power outages from the 2011 earthquake.

International or national funds or loans

Significant international and national funds are being directed to DHC in cities, both for initial development and for rehabilitation. Cities can lobby for such funds to be made available to projects. Velenje, Slovenia, was able to secure a 729,000 € long-term loan with subsidized interest rate and repayment moratorium from Slovenia's Eco Fund for its district cooling system that is based on absorption chillers using waste heat. Across Europe, EU Structural Funds play a key role in helping local and national governments modernize dilapidated district heating infrastructure.

5.2.4 Other sources of finance

Revolving funds

Some local governments are establishing investment funds or green funds to provide subsidies, grants and zero- or low-cost financing, particularly at early stages, for developments that are in the public interest. These endowments can stem from the sale of a city asset (such as city land, shares in a utility, etc.), a surcharge on utility energy bills or innovative sources such as avoided subsidy costs. The funds are designed to be self-sustaining and to grow through returns on investment, interest rates on debt and other revenues. A revolving fund allows for public support of strategic investments without necessitating direct city ownership, and it caps the city's overall involvement in DHC. Often, the fund provides deferral on principal repayment for the first 3–5 years while the system is being constructed and customer revenue has not yet commenced. A revolving fund can support specific district energy starter schemes, designed both to illustrate the feasibility of installing a major heat network and to provide the catalyst for the cost reductions and development of a local supply chain. Capital can be repaid and redeployed in other projects.

Development-based land-value capture strategies

Converting rural to urban land can increase the land value by approximately 400% in Latin America (Smolka, 2014), and this increase can be even higher for high-density urban land. Because such windfalls to the landowner can be captured for public use, land-value capture is described as a "no-brainer," particularly as the value added to the land can be higher than the infrastructure cost needed to develop it. This concept has a long precedent in many countries, based on the "principle of unjustified enrichment" – or the idea that citizens should not accumulate wealth that does not result from their own efforts.

Rural land requisition allows for the development of new urban zones, increasing the value of the land. Future and continuing revenues from selling or leasing land in distinct zones, and capturing taxes from new landowners, provides the finance for infrastructure. This is an excellent demonstration of an integrated approach to district energy. By incorporating urban planning (mixed use zoning, compact land use and high connectivity) with transport and district energy planning, financing of optimal and well-planned district energy projects can be achieved.

6 Revenue management

There are four main revenue generating mechanisms for DHC operators:

- **Heat sales**: Revenues from the sold heat. This revenue source includes sold heat used for heating or cooling at consumer side and a part of the price usually covers also (a part of the) operating costs. The methodology on definition of the (fixed and variable) consumer price is usually defined in the national legislation.
- **Electricity sales**: Revenues from the sold electricity (often as feed-in tariff and in some countries as Denmark electricity is sold in a spot-market) if a CHP technology is used – this is often what makes a DHC business model more viable and lucrative for investors.
- **Connection fees**: Revenues from charging for the connection of a customer to the DHC network. This charge would need to cover at least the capital cost of the connection. This connection fees are not the ones charged at the beginning of the project, which are utilized to finance the initial investment, but those that are collected after the start of the business operation, year by year, by connecting additional consumers, thus creating additional revenues.
- **Operating grants**: Another, more contemporary and innovative revenue generation strategy is also unlinking DH revenues from the delivered (heat) volume through different types of operating grants. An operating subsidy is an extraordinary source of revenue, a payment, usually on behalf of the community, to a commercial entity for the provision of a good or service that would otherwise not be supplied, or would only be supplied at higher prices. Introducing the availability payments for example may be an alternative way to diversify the revenue generating sources.
- **Other and secondary services**: Looking at the DHC business from out of the box perspective can provide a whole new perspective on the revenue generating options. Innovative DHC business models generate revenues also through additional services such as energy efficiency services, power grid balancing services, support in becoming a prosumer, adaptation of new technologies, and also in utilising synergies in the supply of fuel/resources. Typical examples are already explained: entrepreneurship and ESCO models that are successfully combining services up and down along the value chain. A broad set of services offered certainly requires a considerable amount of capital initially. However, there can be always options found that can efficiently complement the core business of providing energy for consumers. Depending on the specific circumstances and demands, this core business can be extended to the whole range of different revenue opportunities, from providing forest works for forest owners, to securing energy efficiency measures. Examples of successful ESCOs show that there are no boundaries when we are talking about the opportunities for secondary revenues.

The basic and first revenue generated by the CHP project is usually the **connection fee for individual consumers**. Initially charged connection fees can represent a small proportion of the investment capital, while additional connection fees after the DHC project erection are considered as generated revenue. It has been already shown in this document, that the connection fees are a useful mechanism and can be used for motivating take-up.

Large industrial and public energy consumers are usually motivated to connect to the DHC by cold rationale. Usually if the long-term energy-costs savings can remunerate the connection fee costs and alternatives mean higher investment costs than the connection fee (which usually is the case), the outsourced heat production is favourable. DHC can represent savings for large consumers also in the form of avoiding the chimney sweeping service, lower operation and maintenance costs and especially in avoiding a cost intensive overhaul of the heating system. Also avoiding emission related taxes can be a cost saving factor for industrial consumers.

Connection to a small DHC system represents a comparable cost of a new and efficient individual heating system for a household. The investment costs of one typical household connection can be up to 4,000 - 5,000 € per connected household. One of the key aspects of successful projects is to ensure a high acceptance of heat consumers. It is important to maximize the heat density (heat sold per area of settlement (kWh/ha). A low heat density may have a negative influence on the project economy and thus on the consumer energy price. Especially in small rural locations and in regions with little positive experience and DHC best practice the initial take-up is critical. As individual households rarely decide on a pure rationale, it is recommended to invest efforts to motivate consumers to connect to the DHC project. One option is to decrease the connection fees and to cover the connection costs within the service price. It has been shown in some projects that at least some consumers prefer to get less energy-cost savings over having high connection costs. In some cases the connection costs can be subsidized through national grant schemes. An innovative approach would be that a municipality would subsidise connection costs for households for the first (demonstration) projects in the municipality.

Heat consumers purchase heat in a variety of qualities, from hot water for domestic heating, sanitary hot water to steam used in industrial processes. Usually the heat consumers can be classified in three basic categories. **Households** are heat consumers with rather standard heat demand parameters on quality and quantity. They usually represent a large amount of small, individual consumers which require considerable client support and accounting efforts. **Public buildings** are consumers with also rather standard heat demand parameters on heat quality and variable quantity needs, as there can be small and also relatively large public consumers (large schools and even hospitals). This category of consumers is an important backbone within the DHC project heat consumption. Public buildings can provide a significant proportion of the load and represent consumers with minimal risk of revenue loss. Third category is **industrial consumers**, which is a specific category with individual demand parameters ranging from heating only to providing external source of heat for industrial processes. This can represent a lucrative option, especially if the heat demand is distributed over the whole year, providing additional full load time for the DHC plant. However, the energy quality demand in the industrial processes can require parameters which are hard to cover within a DHC grid mainly intended for covering heating needs of households and public buildings. The overview of heat quality needed for specific industry is presented in Table 3. In case of large international companies it is frequently that with their global energy consumption, they purchase energy at a very low price in the market. It is frequently hard to provide a competitive energy price for them.

The **heat and service tariff** is usually represented in the variable (operation costs) and fixed part (amortisation, maintenance etc.) and metering charge. The methodology for the definition of the heat price is usually defined in legislation (energy agency or the competent ministry), the prices have to be registered at the energy agency and frequently the framework defines that local or national authority approves all price changes. In case the connection fees are minimised and not covered by a subsidy, that cost has to be covered in the amortisation part of the fixed energy cost. However, there is always allowed some flexibility in pricing approaches:

- A frequently used approach is to bind the DHC energy cost to fossil fuel cost, to guarantee a certain amount or minimal savings. Savings are a significant motivator for the potential consumer and in this model the consumer can be confident to save in comparison to fossil fuels when switching to the DHC. This approach will have less impact for consumers who are already using alternative heating solutions. But consumers who already invested in new heating solutions will anyway less likely decide to connect to the DHC grid. This model also brings a certain risk for the DHC company. In case fossil fuel market price drops significantly, the consequent decrease in heat price will hurt DHC company revenues.
- An innovative approach is to propose a fixed heat and service tariff for a specific time period. This practice was often employed with success to motivate consumer switching to a provider, since it eliminates any uncertainty for consumer regarding the

cost of delivered heat, as the price is fixed. It is important to possess good short to medium term DHC system fuel cost forecasts in order to define the base price to account for that variation in the business model. It is possible to use a fixed energy price with a fixed annual price increase, to account for inflation and forecasted fuel cost increase.

- Another frequently used heat price model is the model of simple discounts according to the size of consumption. Here the heat provider simply decides on the discounts he will be applying according to the amount of heat sold to specific consumers.

It is important to consider that not all households and even public consumers possess enough technical knowledge to understand the variable and fixed price and what is the end annual energy cost that translates into. Therefore it is important to calculate the annual price for a standard house (e.g. 15 – 20 MWh of annual heat demand) and present that price to the household or public representatives. It is advisable to present also comparisons to annual heating costs based on other alternatives.

The **electricity sales** in a DHC project depend on the CHP related framework conditions. If the feed-in tariffs subsidy system is favourable then the electricity sales can have a significant impact on the economy of a DHC project. The additional investment costs into CHP technology are considerable and the operation and maintenance costs connected to its operation also. But in countries with high feed-in tariff the electricity sales in a small to medium DHC size can be as high or higher than the heat sales. However, the feed-in tariff is available only for a specific time period (10-15 years) and it is important to consider the project operation also after that period. Based on the framework the feed-in can be automatically awarded to project that comply with the rules, but in specific frameworks there are tenders where projects which require lowest feed-in tariff are awarded. The risk of developing a project but not receiving the feed-in has to be taken into consideration.

A CHP project can also sell the electricity without the feed-in tariff, per market price. Such projects usually depend on the economy of scale and competent management of the system in order to sell electricity while market price is high. This approach can be combined with electricity to heat technologies, which use electricity at periods of minimal or negative electricity market price. This requires additional efforts in economy management of the plant and is more suitable for existing DHC projects with lower production costs. In medium to long term future, when DHC projects will be common there will be no need for support instruments aimed at motivating development of new DHC projects. At that time CHP projects will have to be able to operate economically at market electricity prices. Same will apply for CHP projects for which the feed-in support will expire.

Business models for DHC can be developed with various different earning logics or strategies to generate revenues, maintain profitability and sustainable business operations. The more operations entrepreneurs can manage, or in other words utilize the value added, the better is the profitability. Of course, this requires efficiency in each stage of the process. As an example of typical heat energy entrepreneurship, forest residues could have a price of 1 €/MWh (paid to the forest owner), as produced wood fuel the price in the silo could be about 14 €/ MWh, while the price of sold heat could be 55 €/MWh (Okkonen, et al. 2010). Therefore, the most value added is in the heat production and distribution stage, but also fuel supply has business opportunities especially when supporting the commercial timber harvesting. Complementary partnerships refer to partnerships where partners take care of the practical operations according to their main areas of expertise. For instance, energy cooperatives have partners who are specializing only in fuel production (forest owners and fuel suppliers), contractors with available machinery, personnel capable in engineering and operating the heating plant and also someone taking care of the accounting and bookkeeping. Operations are often part-time and thus also cost-effective. Networking and subcontracting as an earning logic refers both to the large main companies benefiting from subcontracting some of the tasks, as well as subcontractors benefiting from the networks, scale effects, and technical and economic reliability of the principal company.

7 Cost management

DHC projects are financially intensive projects. The operation has high fixed costs such as insurance, interest expense, property taxes, utilities expenses and depreciation of assets. In DHC systems with high fuel costs there is also a considerable risk of rising fuel costs throughout the project life time. It is important to carefully manage the cost side of the DHC projects which also presents some opportunities or flexibility.

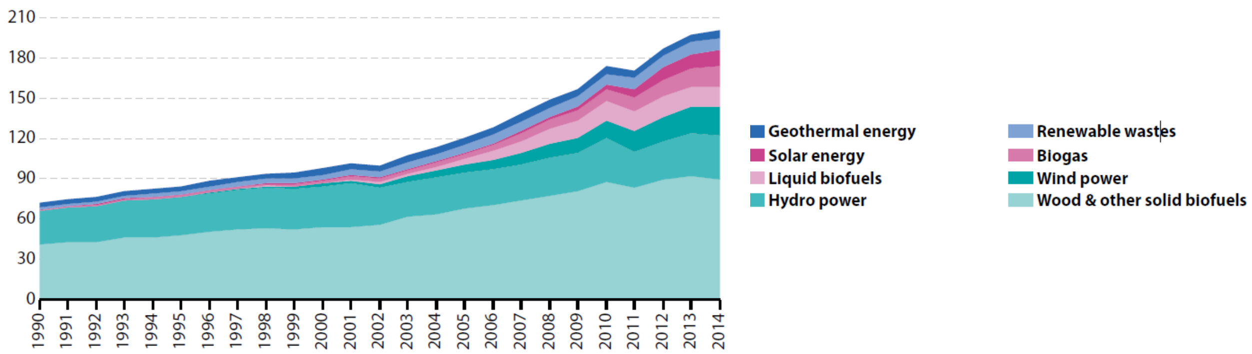


Figure 12. Gross inland consumption of renewables, EU-28, 1990-2014 (Mtoe).[27]

7.1 Energy source costs

DHC projects utilise different sources of energy. They all rely on electric power to run the control systems and pumps and practically every DHC project needs to purchase some fuel for the backup heating systems which are frequently fossil solutions because of short response times. RES based DHC projects utilize biomass, solar energy, geothermal energy or waste energy as the main energy source. Whereas solar and geothermal energy is considered free (apart of special taxes for geothermal energy in some countries to account for aquifer exploitation in non-reinjection systems) and waste energy usually is sold for production costs or even less; in biomass systems fuel costs are by far the largest part of the costs structure. The trend of biomass consumption in EU shows a steady increase from the nineties for solid biofuels and for biogas fuels. The market prices are not stable and it is advisable that DHC business model includes fuel price volatility in the economic simulations.

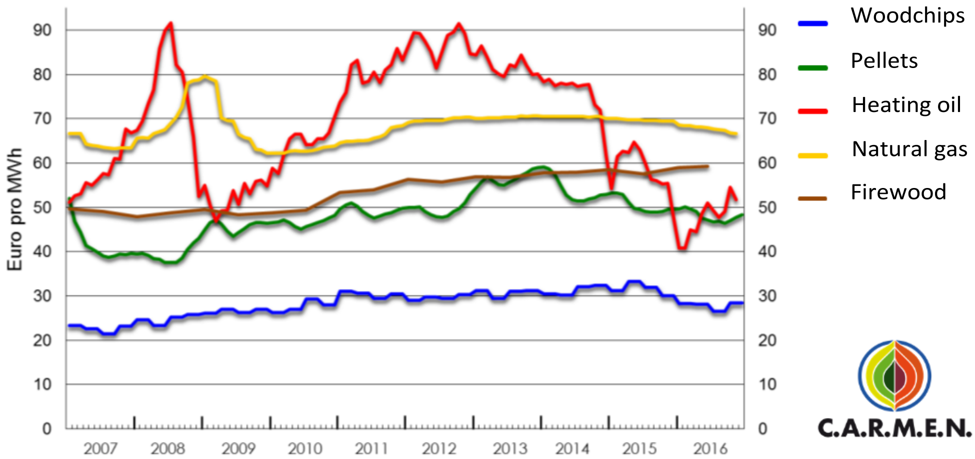


Figure 13. Hard biomass, heating oil and natural gas price trend in Germany, C.A.R.M.E.N.[28]

[27] Eurostat
[28] Source C.A.R.M.E.N. CENTRALES AGRAR-ROHSTOFF MARKETING- UND ENERGIE-NETZWERK E.V, www.carmen-ev.de

The projected price increase can represent the average fuel price change in the last 10 years. It is advisable to use this parameter from a developed country where the biomass market is highly developed and prices are higher. It is also to expect that the prices in undeveloped markets will increase when DHC projects will extend their fuel demand in the national market. Usually the biomass related business models incorporate the annual fuel price increase of 1-2%.

An important part of the fuel supply is the transport and fuel manipulation and preparation costs. In general the biomass for a DHC project should be acquired from the local/regional area. The transport costs and the CO_2 footprint of long transportation of biomass are not sustainable. The usual chipping costs are 3-4 €/t. It is frequently more practical to produce chipping costs based on weight of the biomass. The cost of the biomass on the other hand should be calculated per energy content. Water content has a large impact on the calorific value of biomass. Therefore the price for biomass should be based on the energy content and not on the mere weight of the delivered feedstock and water content of individual shipments has to be measured. E.g. softwood with 40% water content has the energy value of 10.4 MJ/kg whereas softwood with 30% water content has the energy value of 12.6 MJ/kg.

The biomass price should be defined in €/MWh at specific water content e.g. 40%. Each shipment shall be weighted and water content measured. The end biomass price can then be calculated using the formula:

$$\mathbf{P=P_e*(CV_{vf}*(1-WC/100)-(F_{ent}*WC/100))/3.6}$$

P – end biomass price of the shipment (€/t)

P_e – agreed energy price (€/MWh)

CV_{vf} – dry mass energy value (19 MJ/kg)

WC – water content (%)

F_{ent} – enthalpy of vaporization (2.44 MJ/kg)

It is also useful to include a table with defined energy prices regarding the water content in the contract in order to avoid misunderstanding as not all wood sellers are used to sell wood by energy content.

Usually all small modular RES DHC projects utilise electric energy at least in some part (pumps, control…), they usually focus on one or more RES and frequently include fossil backup or peak load systems. In normal systems that uses fossil fuels only for peak capacities, the fossil fuel consumption does not exceeds 10% of the total energy consumption.

An important aspect of biomass DHC is also the option for heat consumers to pay for heat in biomass. Innovative biomass DHC systems are actually relatively large biomass purchasing, transportation, and processing operations. They usually possess space, equipment, manpower, contacts and also cash flow to expand the operation to additional energy source services. Thus some operations enable customers to pay for the heat by biomass. In some cases the DHC operation also offers forestry services (outsourced or own) where again also the forestry services can be payed for in biomass. Some operations include processing and sale of biomass products (firewood, pellets, and woodchips) into their business model.

This cost category often represents the largest portion in the whole cost composition pie. For this reason it is crucial to have a sound and long-term strategy and vision on how to manage this cost category. When our business is dependent on the feedstock, such as biomass, it is important to look for long-term solutions in order to avoid shocks triggered by temporary unavailability or rocketing prices. Long-term contracts, sufficient stocks, back-up plans are all good mitigating strategies if they are planned with competence and care. On the other hand also day-to-day activities have to follow the strategy of optimizing cost as the differences between the businesses that are good in that and those that only react on current needs are abysmal. DHC projects of new generations in highly developed countries in this field, such as Denmark, manage their energy and feedstock costs strategically, almost artistically, along the lines of Wall Street practices. They are trying to adapt to the changing environment continuously, optimizing costs on hourly basis, responding to opportunities and avoiding less favourable developments, acquiring energy or feedstock when the prices are on the low or even negative and selling the energy when the prices are on the high side, adapting the operation of the parts of their energy facilities to tackle everything that comes to hand. This brings the whole new dimension to the DHC business, where the financial and managerial capabilities gain importance over the traditional engineering competences that were crucial in times when DHC technologies were still in the immature phase.

7.2 Operation and maintenance costs

Once a building of the DHC plant has been commissioned, there is a need to maintain its operating efficiency. Operation and maintenance costs represent the ongoing costs of running the operation. The fixed share of O&M includes all costs, which are independent of how the plant is operated, e.g. planned and unplanned maintenance, payments for O&M service agreements, network use of system charges, ordinary or normal alterations of buildings and equipment, care of grounds. The variable O&M costs include consumption of auxiliary materials (water, lubricants, fuel additives), treatment and disposal of residuals, output related repair and maintenance, and spare parts. This cost usually amounts to 1 – 3% of the investment costs but this can vary regarding the technology applied. In general solar technology has lower maintenance costs than e.g. biomass related technologies. It should also be noticed that O&M costs often develop over time. There are many strategies of how to efficiently keep the operation and maintenance costs low. However, the first and the best approach begins with the sound selection of the equipment, materials and suppliers in the planning phase and by strictly following the procedures and the rules of use in the running phase. DHC technologies are in principle mature technologies and a proper use results in the efficient operation of the plant in the scope of the planned operating costs. On the other hand an improper handling, use of low quality materials, inadequate feedstock and other poor business decisions almost always brings the projects cost saving strategy on the road to bankruptcy.

7.3 Cost of management, insurance and lease

Cost of management, insurance and lease represents a cost incurred in the general upkeep of the business and are not attributable to specific products or items. These are simply the costs of the business system e.g. administration, supervision, property, liability and all other insurance, space leasing. Apart from the insurance cost, there is no rule of thumb regarding the size of this cost category as it simply depends on deciding for the most cost and performance effective way of having your business structure ready to perform its core operations. Some systems have their own management staff and do not face any additional management costs, while smaller systems often opt to outsource the entire management of the plant. Some projects are built on own plot and the cost of acquisition is added to the initial investment, while on other occasions the investor chooses or has the possibility to keep the investment cost lower and leases the plot instead. This implies that the cost of management and lease might vary from 0 (projects with own management staff and plot) up to the considerable size (some projects decide to outsource its management entirely and are built on the leased property).

Insurance on the other hand is a primary way of managing risks and is thus one of the crucial and inevitable cost categories. Insurance transfers the cost of a potential loss, damage or other unwanted event to the insurance company in exchange for a fee. No one plans to get involved in negative developments, but unfortunately no project can avoid them entirely, which is why a good and comprehensive insurance arrangement is an absolute must in the DHC business as the consequences of not having a proper one are almost always devastating. Particularly due to the fact that DHC represents the public service provision with an increased number of stakeholders involved. The annual cost of insurance can vary a lot from country to country but a rough estimation is that this costs accounts for around 0.5 – 1.5% of the investment cost.

7.4 Cost of labour

Depending on the project size, the structure of the DHC project operator and strategy, the costs and allocation of employees can vary. Small projects with 1 MW_{th} and simple project without CHP technology require very little or no personnel at all and can be controlled and operated remotely. Such systems can also outsource qualified labour not only for the system management but also for business operations. The maturity of most DHC technologies contributes to that. For this reason, many standard DHC systems can be operated also through the technical staff sharing with the other complementary businesses or public services, as majority of compact systems do not require a full time technical profile on site. Larger system and less mature technologies on the other hand can require constant plant supervision by the staff with appropriate technical training and experience. Also projects which go in the direction of the heat entrepreneurship or ESCO business model, with the abundant set of services require a stronger human resources team, but this is the part of their business strategy and the required profiles in this case are less technical.

8 Guidelines on contractual issues

The heating and cooling business is highly regulated in majority of European states. As DHC is monopolistic by nature there are regulative means to mitigate risks connected to that. District heating is a local affair where customers, employers, owners and production facilities remain principally the same decades after decades all rooted to the same place. Contracts and legislative obligations are ensuring quality of the DHC service and protection of the heat consumer rights.

It is frequently evident, that the contracts are made in insufficient detail. In general, it must be highlighted that the most important contracts in DHC projects should involve professional advice of a lawyer.

A contract is an arrangement between two or more parties that is enforceable by law as a binding legal agreement. In case of DHC projects there are numerous arrangements that have to be addressed[29]:

8.1 Heat supply contracts with the heat consumers

Heat supply should be the core of the DHC plant business. Therefore it makes sense to sign preliminary contracts with potential heat consumers during the planning phase to provide security for the DHC plant investor/operator in the planning phase and on the other hand, the heat consumer has receives security to get connected to the heating grid and to get the heat at a certain price. In view of the DHC project development it is important to secure preliminary contracts with key heat consumers and also with resource/fuel suppliers in the planning phase. As plant operator it is important to secure long term contracts for the fuel purchase and for the heat sale.

The most important basic content of heat supply contracts may include (based on Wagner & Glötzl, 2014):

- Subject of the contract: start time, duration, termination clause
- Heat supply specifications: capacity, quantity and temperature of heat supply, minimum and maximum supply, details on the heat source (renewables)
- Grid issues: map of the grid, location of the heat consumer and heat generator(s)
- Heat transfer station: location of the heat transfer station, ownership of the heat transfer station, transfer point
- Installation costs: costs for the installation of the connection pipes, energy meter, and transfer station, re-establishment of damages after construction
- Heat counting and monitoring: installation and ownership of the heat meter, data transfer and data protection, measurement frequency
- Maintenance and operation: responsibilities for maintenance (e.g. heat transfer station) and operation, electricity for the heat transfer station, calibration of energy meters
- Information: obligations to inform about maintenance work, failures, price changes
- Prices: basic price, connection price, energy price, measurement prices, equipment (rental) prices, heat price calculation
- Payment: instalment payments, final revision and payments, accounting period, default of payment, payment type

[29] The following chapters were elaborated based on the contribution of D. Rutz, WIP, in the framework of the BioVill project

- Access right: for maintenance work, meter reading
- Liabilities: in case of disturbance
- Severability

The price of the heat is the most important part of the contract. Usually the heat tariff is composed of the variable and fixed part and the methodology of tariff definition is defined in the legislation. The defined prices are confirmed by the national authority and frequently also by the local authority (e.g. municipality in Slovenia). Often, the price is differentiated in the following categories, whereas not all categories must be applied:

- Connection price: in €/kW or in € per connection point; unique fee only paid at the first connection of the heat transfer station to the grid
- Basic price: in €/kW connection capacity to cover the fixed cost
- Energy price: in €/MWh heat supplied per year to cover the actual demand related costs
- Measurement price: annual fee for the measurement, maintenance and calibration of the energy meter
- Equipment rental price: in case that the heat transfer station is owned by the grid operator, he may charge a rental fee for it

The heat price for the consumer can be either fixed or is related to an index. This index and the methodology on its calculation must be included in the contract. Depending on framework conditions the heating and cooling energy distributor, which carries out public utility service, has to define the quality and security of the distribution in the system operating instructions (which are strictly defined in national legislation) and if the service is carried out in as commercial activity (usually only possible for small operations) the quality and security of the distribution has to be defined in general contract terms. Frequently the national Energy agency or other competent authority issues mandatory contents of these documents and also publishes the documents in current for all distributors.

System operating instructions and the general terms of contract must be lawful, transparent, objective and non-discriminatory, and prepared in accordance with the national legislation within the legal deadline.

General contract terms are an integral part of the supply contracts and have to be in accordance with the national legislation. They shall be fair and the distributor must inform the client prior to the conclusion of the contract, even if the agreement is made through intermediaries.

Any change in the contractual terms and conditions has to be directly and in a transparent and comprehensible manner communicated to the client at least one month before they come into effect by the distributor (the period is defined in national legislation and may vary between countries).

Also the rights and obligations of consumers in respect of the heat supply are defined in general contract terms. Including technical and other requirements for the safe operation of the system, the conditions and manner of connection to the system and other issues related to the reliability and quality of supply are defined there. It is advisable to carefully define the ownership of heating equipment and buildings to avoid any overlapping or mixed responsibilities.

The DHC operator is obliged to familiarize consumers with these conditions. The DHC operation must define appropriate steps to ensure reliable distribution of energy by providing sufficient capacity and reliability of the distribution system. This should ensure customers feedback about disturbances in the system of energy supply and at the customer's request eliminate the malfunction, which prevents the consumption of heat in the agreed quantity and quality.

Household customer is entitled to emergency care and distributor may not disconnect or limit the consumption of heat below the minimal quantity needed in the circumstances (time of year, temperature conditions, place of residence, health status and other similar circumstances), so that there is no danger to life and health of the client and the persons who reside with him.

8.2 Construction contract and Service contract

Construction contract and Service contract with the Equipment manufacturer or a specialised DHC plant building company (e.g. building company). A common approach in this instance is to have a turn-key service provider that is in charge of the whole construction until commissioning. In this case, the plant operator has to deal contractually only with one other party. It could be also several manufacturers that deliver their equipment to the plant owner. In this case, several contracts are needed. Depending on the DHC project contracts may be needed at the different stages of the project implementation: Purchase agreement, Installation contract and Service and maintenance contract. An important part of these contracts are also the offered equipment warranties.

8.3 Loan and financing contracts

Investment costs for DHC plants utilising RES technologies are considerably high. They are even higher if more technologies are combined in a single plant (e.g. solar and biomass heat generation and seasonal storage). Contracts with banks, investors and shareholders may be needed to collect equity and debt capital for the investment. Banks and investment institutions usually provide own contract forms, however, it is advisable to acquire a specialised consultant or a lawyer for professional advice.

A potential legal form for a new DHC project may be cooperatives, which means that the heat consumers (and other inhabitants of a settlement) have the opportunity to become shareholders by buying shares. Thereby, they may have dedicated rights to get access to information, to participate in assemblies, or to vote. A special contract regulating individual investment and ownership rights should be implemented in this special case.

8.4 Feed-in contract, Contract on connection to the electrical grid with the Electrical grid operator

If the DHC plant is producing power (and heat) it has to be fed into the power grid. The connection to the grid and the sale of electricity is often regulated by national legislation, especially if feed-in tariffs apply. Depending on the legislation, power supply and grid connection contracts may be mandatory or voluntary.

In case of voluntary connection such as e.g. in Germany, and if the issues are well regulated by legislation, dedicated contracts with the grid operator or energy utility may even not be recommended. Often, the power grid operator proposes a contract which shall be carefully evaluated by the biomass plant operator. In case, that a power supply and grid connection contract is mandatory, the most important aspect is related to the feed in tariffs and its requirements.

8.5 Fuel supply contracts

Depending on the RES utilised the fuel costs can represent a marginal part of the costs (e.g. fossil peak capacity in solar DH plants) or a very large proportion of plants costs. Contracts with fuel supplier may involve different parties from energy companies which can supply fossil and biomass fuels to farmers and forestry companies providing biofuels. Fuel delivery may be a critical component in unrestricted DHC plant operation therefore it is important to have good long-term contracts on fuel supply. The contract may include the following important aspects (more aspects for more critical fuel types such as biofuels):

- Type of the fuel

- Quality of the fuel: water content, dry matter content, energy content, ash content, applied standards and specifications, proofs of origin
- Quantity of the fuel: in tons, cubic meters
- Procedure of delivery: delivery to the plant or delivery at source of origin
- Monitoring and control measures: intervals, type and procedures for fuel samples
- Delivery intervals: depends on the storability of the fuel, the storage capacity at the DHC plant
- Duration of the contract: 3-10 years
- Recycling of residues: agreements on recycling digestate or ashes as fertilizer
- Price: fixed price, index-related prices
- Conflict resolution: jurisdiction clauses, penalties, warranties, liabilities, general provisions, etc.

For solid biofuels such as woodchips, pellets, briquettes and logwood the ISO standard ISO 17225-1:2014 on “Solid biofuels -- Fuel specifications and classes” should be applied and referred to in the contract. There are also other related ISO standards for determining the fuel quality and for taking samples.

9 Socio-environmental impacts

DH is increasingly recognised as having a key role in achieving society's environmental objectives e.g. decarbonisation of energy networks. Realisation of this can give increased confidence to those considering new networks.

The concentration of CO_2 in the atmosphere remained below 280 parts per million (ppm) for 800 thousand years until the start of the Industrial Revolution in the eighteenth century. The concentration has risen from 280 ppm in 1780 up to 400 ppm in 2013. The effects of this accelerating trend on our future environment are unknown, but scientists are debating the effects of these trends and the risks of reaching tipping points that may not be reversible.[30] DH systems based on RES can provide energy with reduced emissions of greenhouse gasses. The key environmental benefits:

- It can significantly improve the efficiency of heating and lower carbon emissions. Especially in areas with high fossil fuel dependency and also in areas with high use of hard biomass in old inefficient stoves, as it can be regularly observed in rural areas of less developed countries. Larger plants also have significantly better flu gas cleaning than single, individual boilers.
- DH can make use of waste heat from industrial processes utilising the "free heat" which would otherwise be dissipated to the air or water.
- The pipe work, if installed well, will last for many decades. Whereas energy generation technologies can be adapted and renewed to utilise most efficient technologies and synergies.

But DHC can also have significant social impacts. Depending on the business model chosen, local communities may have opportunities to own and financially benefit from the network. Investment in a large scale network, located in close proximity to proposed new development, may significantly reduce the developer's cost of compliance with Building Regulations. It may even be the factor that enables development to go ahead at all as has been shown in Güssing in the last century where a whole industrial area emerged from Greenfield investments basing on supply with cheap heat energy from RES, drastically increasing jobs and decreasing commuting. Nevertheless, DHC systems can even improve real-estate value. Alto cooperatives have shown that DHC systems can represent an interesting focal point of local economic chains and circular economies. New players often find a position between the end user and the energy supplier/grid operator, and new businesses are created.

DHC is reliant on a consistent or growing customer base. In some countries residents would prefer DH to central heating systems, due to perceived reliability and availability of heat from a central DH. In Finland DH is perceived as incumbent heat supply technology and individual boilers are perceived as unreliable. However, even if consumers are interested in green alternatives, there is no guarantee they will be willing to pay more for them. Customers may even find themselves tied into a heating system that they are unhappy with. A focus on customer service and competitive pricing is considered important. An important part of that is also fuel transport and manipulation in biomass or waste systems. Transport and manipulation of fuel may cause disruption and noise. Municipal planning can define possible locations of an energy generating plant and in that way manage the negative environmental impacts such as noise, emissions and waste from the heat generating plant.

Utilisation of local/regional available RES increases security of energy supply and lowers dependency on import of energy sources. It can also have a very positive impact on energy price stability and can represent a competitive source of energy providing similar prices as fossil alternatives or even significantly lower prices than fossil alternative.

[30] www.e-hub.org/environmental-cost-renewable-energy.html

Cooperative investments into DHC systems are a well-established and successful ownership model for DHC projects. An important social impact is that this model facilitates social bonds in the community.

10 Best practice examples

There are numerous best practice examples of successful DHC project applying innovative business models and ideas in Europe. In this paragraph some of the DHC project representing innovative approaches and business models are presented.

10.1 Brædstrup District Heating[31]

Brædstrup is located in the middle of Jutland in Denmark. In the city a consumer owned DH company is supplying almost 1,500 consumers. It is an excellent example of the cooperative ownership model and an DH project with a clear strategy to tackle every opportunity on the market to make district heating more efficient and cheaper for the heat consumers. The DH plant started as an natural gas CHP and boiler system. Today the plant combines natural gas CHP technology with solar heating, seasonal storage units, electric boilers and heat pump technology (high pressure screw compressor). The technologies are combined in a smart way, utilising CHP when electricity prices are high and electrical heating when electricity prices in the spot market are low or even negative.

That way Brædstrup DH has been a frontrunner in Denmark in how to make district heating efficient, cheap for the consumers and environmentally friendly at the same time over the last 10 years. This is done through activities in the electricity market, smart metering and introduction of service visits and support to improvement of house installations. Increasing the efficiency and optimizing the production and distribution facilities in terms of technical economical and environmental aspects are central parts of the district heating company´s future policy.

In 2005 no Danish natural gas fired CHP had solar district heating. Brædstrup DH made design calculations showing that solar district heating combined with CHP in an open electricity market could be a feasible solution. The electricity prices are in periods so low, that the engine is stopped and the heat production takes place on natural gas boilers, making solar district heating a feasible solution.

The consumers' benefit of the activities has been less pollution from reduction in natural gas consumption and low heat prices; Brædstrup DH is among the 25 % cheapest DH plants in Denmark. The heat price for a standard house in Denmark with annual heat needs 18.1 MWh and 130 m^2 of heated space (incl. tax, excl. capital costs) amounts to 63 EUR/MWh or 1,721 EUR/year. All house installations are checked every second year by the utility and all consumers can find key figures for their own consumption at Brædstrup DH´s homepage via a personal link. All large decisions are taken by the annual general assembly, where all consumers are invited and have a vote. Project preparation with local plan and landscaping has been carried out in co-operation with Horsens Municipality to integrate solar plants in the landscape and utilize them as recreation areas. A presentation of the plant can be seen in this link: http://dkfilm.jsmediatools.com/dk/200902/braedstrupfjernvarmeUK/.

10.2 District Heating in Bornholm and Bornholms Forsyning[32]

The isle of Bornholm is the most eastern part of Demark. Nine town areas on the island of are supplied by district heating. The DH is a part of a broader 2025 Energy Strategy for Bornholm that envisions turning Bornholm into a carbon-neutral society based on sustainable and renewable energy by 2025.

[31] Based uppon Best Practice Examples for small modular renewable heating and cooling in Europe www.coolheating.eu/images/downloads/D2.1_Best_Practice.pdf
[32] Based uppon Best Practice Examples for small modular renewable heating and cooling in Europe www.coolheating.eu/images/downloads/D2.1_Best_Practice.pdf

The production of heat is based on various types of technologies; In Rønne, the heat supply is primarily based on heat from waste incineration and excess heat from electricity production based on wood chips and coal (CHP). In Nexø Heat Supply was established in 1989 and all heat is produced on a straw boiler. An oil boiler is used as back-up. The heat production from the plant in Klemensker is also based on straw from. The plant in Aakirkeby is a newer plant from 2010 where the heat is produced in a wood chip boiler. The heat production in Vestbornholm / Hasle is based on biomass from a straw boiler and wood pellet boiler as peak load. This is also the case for the new plant in Østerlars from 2013, where heat is produced based on a straw boiler including wood chip pellet boiler and electric boiler as peak load units.

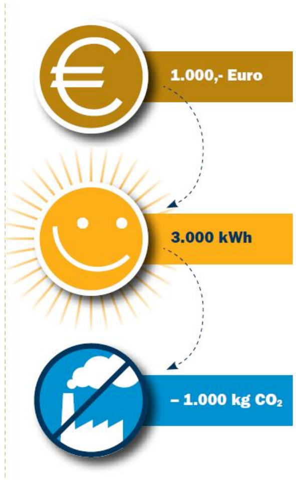
The DH plants are consumer owned and the operation is divided on three utilities. The consumer price amounts to 87 EUR/year (2016) with a fixed fee of 3.83 EUR/m^2 of heated space, plus 383 EUR/year. For a standard house with annual heating needs of 18.1 MWh and 130 m^2 of heated space (incl. tax, excl. capital costs) this amounts to a total 2,500 EUR/year. The utilities invest a lot into motivating of citizens to join the DH with special efforts put into transparent operation and a "package" offer for citizens that almost everybody can pay without taking a loan. The "package" offer includes:

- Heating pipes is installed into the building
- The old oil-burner and oil-tank is removed
- A new district heating unit is installed
- Price: 17.000 kr. (2.300 Euro) VAT incl.
- Possibility of tax reduction ”håndværkerfradrag” (half of the price can be deducted in tax)

The DH investments in Bornholm island are financed by municipal loan guarantees which enable cheap loans in ”Kommunekredit”. Loans are running for 25 years with fixed interest (less than 2% in interest). The investment in the pipe system is in average 100.000 kr./consumer - small and large (app. 13.500 Euro). All works are put out to tender: pipes, digging and welding, plumbing work, district heating units.

10.3 SOLID Invest[33]

SOLID is realising ESCO solar heating plant concepts for the customer, where the customer pays only for kWh of solar heat and not also for the installation. Due to changed financial framework conditions in Europe, it has become more difficult for SMEs to get loans for new projects. Therefore in November 2013 SOLID has launched a new investment model for solar thermal systems with public participation, called SOLID Invest. The model provides citizens the opportunity to take responsibility for renewable energy developments by supporting the realisation of new solar thermal projects on regional and global level.



SOLID Invest works on the Lending-based Crowdfunding e.g. Crowd-lending approach. Instead of one big investor many small investors lend their money. In return they get back an interest yield every year and in the end of the binding period they get back their loan.

The key stakeholder is the SOLID International GmbH, the investment company which takes the loans from individual investors. It manages the invested money and supervises individual ESCO companies. It communicates to existing and

[33] Based uppon the Business models collected in the SDH project, solar-district-heating.eu/.

potential investors. It also pays for the annual interests to the investors and pays back the loan after end of the contract. The minimum duration of the contract is 5 years. After this period the contract can be cancelled by each party.

In the model the target group of wealthy green minded individuals was defined. This target group of private investors was reached by marketing events in Graz and other cities and also through media campaigns. Individuals invested from 2,000 to 15,000 €.

As all financial business is under the auspices of the financial market supervision authority, the lending based Crowdfunding model has to comply with the rules of the Austrian Finanzmarktaufsicht (FMA).

Another important stakeholder group are the potential energy consumers. The energy purchasers have to show financial commitment to the project in the beginning and also give guarantees for a long term heat purchase – normally 8 to 20 years.

Crowd-lending based equity is relatively expensive but needed in the financial construction. Currently SOLID Invest is at an annual interest rate of 4.0 %, while bank loans can have much lower interest rates. Therefore a part of the investment is covered by the loan capital. In the financial plan the crowdfunding equity has a share of 15-20 % of the total investment. The remaining 75-80 % is funded by public funding for renewable energy, the energy consumers and (mainly) by bank loans.

This highly innovative approach provides high transparency and stakeholder involvement. It has a high potential to be replicated by other interested parties. It is also an time consuming and has to provide continuous balancing between supply (financing of existing and new solar projects) and demand (existing and new investments).As this is also a relatively new financing and ownership model it is important to monitor framework and legislation change relevant for crowdfunding.

More information is available at www.solid.at/invest.

10.4 ESCO Solacomplex AG - Bioenergiedorf Büsingen[34]

Solarcomplex AG is a regional energy supplier in south Germany. The aim of Solarcomplex is to transform the energy supply of the Lake of Constance area to renewable energies until 2030. One of the business models is to transform entire villages in Baden-Württemberg to 'bio energy villages' (Bioenergiedörfer) by building renewable DH nets for heat and photovoltaic plants for electricity. All inhabitants of the villages are involved in the projects at an early stage, in order to achieve a high share of participation and connected buildings.

Büsingen is the seventh bio energy village of Solarcomplex AG. A DH net was to be built to provide the houses of Büsingen with a mix of biomass and solar heat. Solar thermal should be used to cover the heat demand in summer and the dimension of the plant foreseen was around 1,000 m². Büsingen is the first German bio energy village realized with solar district heating. The plant is therefore an important best practice example for the bio energy villages in Germany.

[34] Based uppon the available data from the www.solarcomplex.de and the case study report from the SDH project solar-district-heating.eu/Documents/SDHCasestudies.aspx

Figure 14: Heating house of the bioenergy village Büsingen. (Source: Solarcomplex)

The overall investment costs for the operation amounted to 3.5 M€ and the operation received support of The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) through the 'Marktanreizprogramm' (MAP) supports the development of renewable energies in the heat market: 1) large solar plants feeding into a heat net are supported with KfW loan with redemption subsidies up to 40 % of the investment cost. 2) Existing district heating nets supplying renewable heat and substations are supported via KfW loan with redemption subsidies of 60 € per meter pipe and 1,800 € per substation. 3) For heat storages bigger than 10 m³, the redemption subsidy is 250 €/m³. The Federal Ministry of Economics and Technology (BMWi), together with BMU supports research activities: for especially innovative pilot plants, incentives can be obtained for investment and related research. 4) The region of Baden-Württemberg gives financial support to the realisation of heating networks in bio energy villages.

The heat consumers (mostly private households), did not need to pay a connection fee, therefore many building owners connected their internal heating system to the DH system. The project was implemented by the municipal administration and the company Solarcomplex, which installed the technical equipment and is now responsible for the plant operation. Citizens got periodically informed about the project progression, the realized measures and the payment conditions for the heat production.

The Bioenergiedorf Büsingen showes that solar DH can be an interesting technology also in rural areas. Since the potential of biomass is limited and rising costs for wood chips influence the profitability, solar heat can help achieve long-time stable heat costs. Moreover the concept of bio energy villages will improve the regional economy (local craftsmen, building companies, consulting engineers, wood chips, etc.).

Sometimes the initiator of a bio energy village is not a company but dedicated citizens in co-operation with the community, local craftsmen, building companies and consulting engineers. As a form of organisation registered co-operatives are often chosen, which allows the citizens a high degree of co-determination and influence in combination with a limited liability. The financial ambition is not profit maximisation but to achieve a long-term favourable price (cost-covering) using renewable energies. Through the participation of the residents social cohesion is strengthened, the collaboration helps to achieve better acceptability and voluntary workings help to cut costs.

Büsingen received several awards by the Ministry of Finance and Economics Baden-Württemberg (Initiative 2013/2014 Sustainable designed living Houses. Quarters) and the Georg-Salvamoser-Award, which awards innovative solar projects.

10.5 St. Peter cooperative[35]

With 2.550 inhabitants, the idyllic St. Peter settlement lies in the middle of the natural park "Südschwarzwald" in Germany and stretches on a plateau from 700 m to 1200 m above sea level. The total land area of 3,593 ha is distributed over 1,792 ha of agricultural land, 1,626 ha of forest land and 146 ha of settlements,

Climate change and rising energy costs, the finite nature of fossil fuels, the increasing energy demand and the warming of our planet, have inhabitants of St. Peter accepted as challenges and have initiated the energy transition towards decentralized and renewable energy generation. Sustainable energy production has a long tradition in Schwarzwald. For centuries hydropower has been used in mills and sawmills and local biomass for heating.

The developed energy concept of Schwarzwald has traditionally been based on sustainable energy sources that nature offers in its immediate surroundings: Sun - water - wind – biomass. The use of photovoltaics, thermal solar collectors, wind and hydropower as well as the supply of district heating to the municipality contribute to fulfilling the criteria for a bioenergy village.

An important part in this development is the Bürgerenergie St. Peter eG cooperative that resulted from the citizen initiative (initiator: Daniel Rösch, sculptor and artist). The cooperative is providing a centralised heating supply for the municipality of St. Peter as well as generates electricity through biomass CHP. The cooperative has planned, erected and operates the CHP plant and the DH grid and supplies its members with heating. The needed wood chips are mostly from the forests of St. Peter.

The Bürgerergie St. Peter eG was funded in summer 2008 by 11 founding members in voluntary activity. Concepts were developed, possible implementation models were researched and existing plants in Germany and abroad were visited.

Funding of 6.4 M € was realised which includes private equity and subsidies. The cooperative is the owner of the DH system.

The investment costs for the complete project which in addition to the biomass DH includes six local windturbines and photovoltaic instalations amounted to app. 6.4 M €. The project was financed by the Bürgerenergie St. Peter eG whereas the needed capital of 700,000 € was gathered in form of membership fees and private loans from cooperative members. Each cooperative member payed an annual contribution of 500 EUR. Members, who were connected to the DH grid and receive heat from the network, pay an annual contribution of 1,500 EUR. With these annual fees a sum of 339,000 EUR was contributed to the project. There was also the opportunity for cooperative members to financially participate in the granting of a private loan. The loans are between 1,000—25,000 EUR per person with an interest rate of 6%. Through this process, it was possible to collect another 361,000 EUR as private equity for the cooperative.

The investment structure was closed with 4.5 M € from the funding program Renewable Energies Premium and the project was supported by the national funding bank Kreditanstalt für Wiederaufbau who offered a repayment bonus of 1.25 million EUR. Furthermore, the project received subsidies from the state of Baden-Württemberg (200,000 €) using the European Regional Development Fund (ERDF).

[35] Based uppon www.buergerenergie-st-peter.de/ and issuu.com/zweihochdrei/docs/st-peter_bioenergiedorf?backgroundColor=%23222222

Figure 15. Founding members of the cooperative in St. Peter (Source: Bürger Energie St Peter eG)

All the benefits arising from the production of electricity and the operation of district heating are directly benefiting the members of the cooperative. All citizens of St. Peter, connected to the DH network or not, can become members of the cooperative and thereby reaffirm their own commitment to environmental protection. The cooperative works on the basis of a statute. The management includes 2 management board members and a 5-member supervisory board.

The DHC plant includes a wood pellet wood gas CHP with 270 kW_{th} and 180 kW_{el} power, a 1,700 kW_{th} wood-chip biomass boiler and 2 oil peak / emergency boilers with outputs of 920 kW_{th} and 1,750 kW_{th}. The plant also includes 2 heat storage buffers with 48,000 l to compensate daily peaks. The DH grid is 12 km long and utilises a variable flow temperate of 75 – 100 ºC, depending on outdoor temperatures. The return temperature is 50 ºC.

The DHC plant generates heat and electricity using biomass. The electricity is fed into the public electricity grid and using the generated hot water, the houses in the village centre are supplied by through a DH network. At the consumer, heating and process water are provided by a heat exchanger.

A powerful electrostatic filter ensures emissions from the plant are not harmful for environment. The conversion to ecological biomass heating saves 3,500 tons of CO_2 emissions annually. The dependence on fossil fuel is reduced. The heating oil consumption is reduced by 900,000 l per year.

10.6 Heating with woodchips in Güttenbach[36]

The biomass heating plant and district heating grid in Güttenbach (Austria) was built in 1997. The boilers are fired with wood chips from local forests. There are two boilers installed, one biomass boiler with 1 MW capacity and one oil boiler for peak load and backup with 1.3 MW capacity. The village of Güttenbach has about 900 inhabitants and an area of 16 km². The district heating grid has a length of 12 km with about 240 connected consumers. Each year there are 5,200 MWh heat sold to the consumers.

In Güttenbach the district heating company developed a new concept for mobilizing unused resources from the local forests as energy wood. In this region there are a lot of private forest owners. Caused by the demographic change, there is an uncoordinated approach by the actors along the value chain from the forest to the energy consumption of wood. That’s why wood is unused now and there is no gain for owners or other companies.

For these reasons, a concept for improved biomass logistics has been prepared by an economic incentive for forest owners to provide forest biomass for sale as energy wood and thus to achieve a mobilization of unused forest resources. On the one hand the burden on

[36] Based uppon Best Practice Examples for small modular renewable heating and cooling in Europe www.coolheating.eu/images/downloads/D2.1_Best_Practice.pdf

forest owners was reduced to a minimum and on the other hand a transparent and fair billing system was introduced.

With this concept the following targets should be reached:
- Development of a local energy wood market
- Transparent marketing- and purchasing structure
- Central contact persons for procurement logistics
- Reappraise economic incentive for forest owners to thinning residues
- Mobilizing unused energy wood resources of small sized woodland owners
- Compensation of annual supply and demand fluctuation
- Prevention of polluting the lumberyard outside the forest
- Regional added value

The key issue in this concept is to build smaller energy wood storage yards, where woodland owners can store and sell their wood. At the yard the energy wood is dried, chopped and stored. If there is a demand of wood chips at a power station, the wood chips are transported from the yard to the power station. In the following figure the concept is visualized. Route 1 is not adequate due to the fact that supply and demand varies significantly and the storage capacity of power plants is also limited. This fluctuation can be compensated with wood storage yards where the wood chips are stored till they are needed in the power plant.

All details about the concept (German version):
http://www.pemures.com/cms/images/downloads/Energieholzbereitstellung_Konzept.pdf

Slovenian version of concept:
http://www.pemures.com/cms/images/downloads/Energieholzbereitstellung-Konzept-SI.pdf

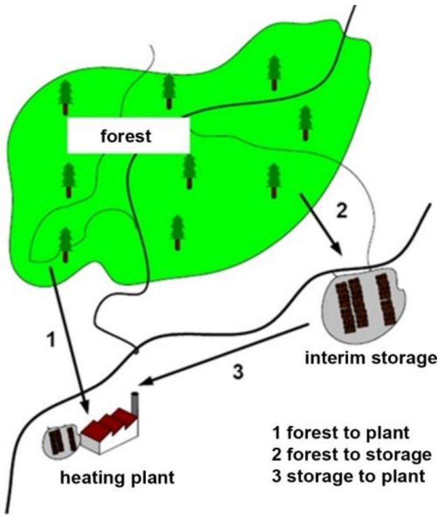


Figure 16: Biomass heating plant with 1MW biomass boiler and 1.3 MW oil peak load boiler (Source: EEE GmbH); Concept for mobilizing unused resources from local forests in Güttenbach with an interim storage

10.7 Heating with woodchips Biomasse Kaisserwald[37]

The Biomass Kaiserwald is a cooperative founded in 2005, which operates DH systems in the districts of Güssing and Oberwart (Austria), thus providing apartments and larger buildings (for example, schools, public objects and apartment blocks) with heat in micro DH systems, which are fired with biomass (wood chips) from the local forests.

[37] This paragraph is based on the publication Landwirt als Energieproduzent, project PEMURES, www.pemures.com (available in german and slovene language)

The cooperative Kaisserswald consists of three local farmers. They not only produce the fuel but can also build small biomass heating plants to supply heat to neighbours, public buildings, apartments or commercial enterprises. The cooperative, invests in the entire biomass plant plus the structural measures, as well as in the heat distribution network. The cooperative also operates, maintains and provides potential repairs of the heating system. The local heating plants are financed with own assets and the one-off connection fee for consumers and possible subsidies.

The biomass is obtained from regional farmers and municipalities. There are no contractors. Among other things, the wood comes also from the Burgenland Forest Association. The energy supply remains in the region enabling new value chains. In a year 500 to 600 t of wood chips are needed. Each micro DH plant is being supplied by the cooperative.

11 Summary

Heating and cooling consumes half of EU's energy. District heating and cooling is a proven solution that has been deployed for many years in a growing number of cities worldwide. It incorporates a diversity of technologies that seek to develop synergies between the production, storage and supply of heat, cooling, production of domestic hot water and production of electricity. District heating enables the use of a variety of energy sources which are often wasted, as well as the use of renewable heat. The future standard is referred to as the fourth generation systems, which operate at lower temperatures and have reduced heat losses compared to previous generations. These systems make it feasible to connect to areas with low energy density and can use diverse sources of heat, including low-grade waste heat, and can also allow consumers to supply heat as well. Through heat storage, smart systems and flexible supply, these systems are an inexpensive solution for creating the flexibility required to integrate high levels of variable renewable energy into the electricity grid.

District cooling has huge potential in both developed and developing countries. In countries with a warm climate air-conditioning demand accounts for large proportions of annual energy consumption. An extreme example is Kuwait where air conditioning in buildings accounts to 50% of annual energy consumption. There district cooling could reduce peak power demand by annual electricity consumption by 44% compared to a conventional air-cooled system (Ben- Nakhi, 2011). District cooling is a technology that is slowly gaining attention in some developing country cities because of its ability to alleviate stresses on power systems caused by air conditioning.[38] It is shown in this document that also district heating can help balance power grids – when electricity is used in off-peak periods to generate heat, which is stored and used when needed. This can help balance power grids, but can also improve DHC economy as utilisation of electricity in off-peak time's means very low electricity prices or even negative electricity prices.

The benefits of district cooling are felt by various stakeholders. Consumers benefit from lower and/or more stable cooling costs (if the system is well placed) and from not having to house and maintain individual cooling solutions. Meanwhile, municipal, regional or national electricity utilities are able to provide less electricity at peak demand and overall, reducing the need for transmission system upgrades and capacity additions. Finally, the local economy could potentially benefit greatly from fewer blackouts, reduced need for backup generation in individual buildings, lower electricity prices, and cheaper and easier reduction of refrigerants such as HCFCs and HFCs in traditional air-conditioning units[39]. Nevertheless, district cooling can represent an important option for expansion of business models of existing DH projects in future, when technology will be cheaper and DH project will have to adapt to changing conditions (expiry of subsidies, lower production costs etc.).

There is a huge potential for district energy in both cooling and heating, depending on the local climate and requirements. Energy markets in many of developing countries are less liberalized and less privatized than in developed countries. District energy requires strong public sector involvement in project development and operation, and the model of publicly owned energy services in many developing countries may provide a strong platform for project development. In some countries, problems such as access to capital, expertise and institutional inefficiencies may need to be addressed. And especially in less developed countries it is important to inform population, public and private institutions/companies on posibilites in DHC.

[38] An Eu Strategy On Heating And Cooling, ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v14.pdf

[39] District energy in cities: Unlocking the potential of energy efficiency and renewable energy", Global district energy in cities initiative. UNEP www.unep.org/energy/portals/50177/DES_District_Energy_Report_full_02_d.pdf

But it should be kept in mind that the implementation of renewable energy sources cannot and should not be a substitute for energy efficiency in buildings and processes. Long-term stability of costs for heat and cooling energy is based on the efficient use of local biofuels, geothermal and solar energy on the one hand and the increase number of heat consumers that bears indirect costs of heating and cooling service on the other hand.

A key best practice is to build on the city's heat/cooling assessment and on the stakeholder engagement and institutional coordination developed in this process to develop a detailed heat/cooling map of the city. The first step is to collect spatial data on areas of dense heat or cool demand, local energy assets such as excess waste heat, renewable heat, free cooling and distribution infrastructure. This will enable the identification of individual projects, future interconnection potential, future growth in the city and required policy interventions. Where a city is unable to develop city-wide energy mapping due to a lack of funds, mapping can focus on high-potential areas such as the Central Business District or zones/areas of new development.

Another best practice is to start developing an institutional structure for multi-stakeholder coordination and to use data input from stakeholders, such as the distribution utility, public buildings, housing associations, etc. Where the institutional capacity or funding does not exist to carry out a thorough energy mapping, a city can explore the following options:

- Develop a public-private partnership in planning, coordination and project development. Mobilize private partners on the basis of the potential benefits and the objective to scale up district energy to help with strategy development and capacity-building
- Identify areas in the city that have high heat or cooling demand, such as commercial districts or new developments. Develop an energy map for these specific areas in collaboration with any private sector actors, and assess potential benefits from DHC deployment in those specific areas. Such potential benefits can legitimize – and facilitate funding for – the demonstration project.
- Consider seeking funding for demonstration projects at the national or international level, such as through Vertically Integrated National Appropriate Mitigation Action s (V-NAMAs), specialized grant schemes as NER300, development bank grants and EU structural funds, as long as the potential benefits for the project (CO_2 mitigation; demand reduction, etc.) are highlighted.
- Use the positive experience and negative impacts from existing demonstration projects, and the benefits showcased, to leverage further finance for full energy mapping in the city.
- Use demonstration projects to develop the institutional frameworks and capacity-building that is vital for the development of energy mapping. The city can then scale up capacity and institutional frameworks in a stepwise manner, using lessons from the demonstration project.

Information and concepts available in this document can be further supported by other outcomes of the CoolHeating project such as the Guidelines for initiators of small heating-cooling grids, Handbook on Small Modular Renewable Heating and Cooling Grids and the Economic calculation tool for simple economic assessments of DHC business models. These documents are available on the CoolHeating web page http://www.coolheating.eu.

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